THE STATE AGRICULTURAL COLLEGE
OF COLORADO

THE FOURTEENTH ANNUAL REPORT

OF

The Agricultural Experiment Station

For 1901

LETTER OF TRANSMITTAL.

To His Excellency,

JAMES B. ORMAN,

Governor of Colorado.

In accordance with the conditions of the act of Congress which requires a full and detailed report of the operations of the Experiment Station, I have the honor to present herewith the Fourteenth Annual Report.

The financial statement is for the United States fiscal year ending June 30; the other portions being reported substantially for the current year.

L. G. CARPENTER, Director.

The Agricultural Experiment Station,

FORT COLLINS, COLORADO.

THE STATE BOARD OF AGRICULTURE.

		Term Expires
Hon. B. F. ROCKAFELLOW,	Canon City.	1903
Mrs. ELIZA F. ROUTT,	Denver.	1903
Hon. P. F. SHARP, *President*,	Denver.	1905
Hon. JESSE HARRIS,	Fort Collins.	1905
Hon. HARLAN THOMAS,	Denver.	1907
*Hon. P. A. AMISS,	Pruden.	
†Hon. W. R. THOMAS,	Denver.	1907
Hon. JAMES L. CHATFIELD,	Gypsum.	1909
Hon. B. U. DYE,	Rockyford.	1909

Governor JAMES B. ORMAN,
President BARTON O. AYLESWORTH, } *ex-officio*.

* Resigned April, 1901.
† Elected by the Board to fill vacancy.

Executive Committee—to April 30.

P. F. SHARP, *Chairman*. B. F. ROCKAFELLOW.
P. A. AMISS. JAMES L. CHATFIELD. JESSE HARRIS.

Executive Committee in Charge.

P. F. SHARP, *Chairman*.
B. F. ROCKAFELLOW. JESSE HARRIS.

STATION STAFF.

L. G. CARPENTER, M. S., *Director*,	Irrigation Engineer
C. P. GILLETTE, M. S.,	Entomologist
W. P. HEADDEN, A. M., Ph. D.,	Chemist
WENDELL PADDOCK, M. S.,	Horticulturist
B. C. BUFFUM, M. S.,	Agriculturist
R. E. TRIMBLE, B. S.,	Assistant Irrigation Engineer
E. D. BALL, M. S,	Assistant Entomologist
*E. S. G. TITUS, B. S.,	Acting Assistant Entomologist
A, H. DANIELSON, B. S.,	Assistant Agriculturist and Photographer
F. M. ROLFS, B. S.,	Assistant Horticulturist
F. C. ALFORD, M. S.,	Assistant Chemist
EARL DOUGLASS, M. S.,	Assistant Chemist

Officers.

President BARTON O. AYLESWORTH, A. M., LL. D.

L. G. CARPENTER, M. S.,	Director
A. M. HAWLEY,	Secretary
†W. R. HEADDEN, B. S.,	Stenographer and Clerk
A. D. MILLIGAN,	Stenographer and Clerk

*To June 1, 1901.
†To October 1, 1901.

THE EXPERIMENTAL PLATS.

SECRETARY'S FINANCIAL REPORT OF THE COLORADO AGRICULTURAL EXPERIMENT STATION FOR FISCAL YEAR ENDING JUNE 30, 1901.

Dr.	U. S. Fund.	Special Fund.	Total.
From the Treasurer of the United States, as per act of Congress approved March 2. 1887	$15,000.00		
Balance July 1, 1900		$ 317.47	
Farm products		1,280.10	
Miscellaneous		306.87	$16,904.44
By Salaries	$10,773.53	$ 209.51	$10,983.04
Labor	691.20	136.61	827.81
Publications	1,546.99	179.80	1,726.79
Postage and Stationery	335.17	217.17	552.34
Freight and Express	15.82		15.82
Heat, Light, Water, Power	0	0	0
Chemical Supplies	6.43		6.43
Seeds, Plants, Sundrry Supplies	169.42	4.90	174.32
Fertilizers	156.00		156.00
Feeding Stuffs	10.60		10.60
Library	37.74		37.74
Tools, Implements, Machinery	19.15	14.50	33.65
Furniture and Fixtures	108.45	333.33	441.78
Scientific Apparatus	84.92	349,02	433.94
Live Stock	39.50		39.50
Traveling Expenses	944.59	113.70	1,058.29
Contingent Expenses	10.00	47.50	57.50
Building and Repairs	50.49		50.49
Total	$15,000.00	$1,606.04	$16,606.04
Balance June 30, 1901		298.40	298.40
	$15,000.00	$1,904.44	$16,904.44

A. M. HAWLEY,
Secretary.

REPORT OF THE DIRECTOR.

To The Executive Committee:

Gentlemen: I have the honor to present the following report as Director of the Experiment Station for the present calendar year. This also includes the reports of progress of the different sections.

FINANCES.

As the fiscal year ends June 30, it is more convenient to report the situation at that time. For the fiscal year ending June 30, 1901, the receipts from all sources amounted to $16,280.17. There was a balance of $317.47 brought forward from the previous fiscal year, and $298.40 carried forward, thus making the total expenditure $16,606.04. For the current fiscal year the estimate of receipts is larger, due to the funds received from sales of property at substations.

PUBLICATIONS.

Since the 1st of December, 1900, we have issued eight bulletins, one of which was in two editions. Two bulletins are now in press. We also issued six press bulletins and twenty-six special river bulletins, and two extracts from the regular report. The editions of the regular bulletins have had to be increased from 6,000 to 8,500. This means a considerable additional expense. The total number of copies of the report issued during the year was 1,500; and of the bulletins 51,000; of the press bulletins 22,000; of the river bulletins 10,000, making a total of over 85,000 copies, which have been distributed during the year. The number of pages thus distributed is over 1,500,000. In the number of pages and in the number of publications issued during the year we shall equal almost any station in the United States. 100 volumes of the publications of last year were bound with cloth covers for the use of offices and libraries and places where it was desirable to have bound copies. This has been a very desirable and acceptable edition.

Progress has been made during the year in binding the bulletins received from other Stations. This step has been necessary in order to preserve records which are very important in Station work. A great deal of time has been taken in attempting to complete our files of bulletins. We still lack some bulletins from a number of states, but the sets are gradually being completed, and as fast as this is being done, they are bound.

During the year the substations and the problems arising from them have taken an undue amount of time. Their affairs are now, however, more simplified than before, and it is hoped that in the future they will be in better condition. It is evident that in order that the substations may be an integral part of the main Station, so that the work done there may be of service in the larger plans of the Station, that the substations need be in closer touch with the main Station, and that there should be closer supervision. I will give a more complete statement of the affairs of the substations before closing this report.

THE PROBLEMS OF THE STATE.

This State is so large and with such a variety of conditions that the number of problems pressing for solution is greater than we can take up. When we recall that Colorado is as large as the states of New York, Maine, Vermont, New Hampshire, Massachusetts and Rhode Island together, and that in this area equal to Colorado, the six stations supported from the Hatch fund have not only been kept busy with the problems of this equal area, but the demand for their work has required several State Stations in addition, and that these States have appropriated over $100,000 in addition to the $90,000 from the government, it becomes evident that we cannot take up all the questions which arise in the area when we have an income of not over one-thirteenth as much.

There are so many problems peculiar to this State in the solution of which we can obtain little help from the investigations of other States, that our policy should be to refrain from lines where their investigations may apply to our conditions. There is even then far more work than we can take up. The temptation has been to take up problems and not carry them through to completion.

The development of the sugar beet industry is a gratifying result of the work of this Station, and of the other Stations in the United States as well as the Department of Agriculture. It is an industry of great promise, the rise of which is purely one of scientific investigation.

The work of the Station has proceeded pleasantly, and while we can realize defects, yet we can see a material improvement. In considering the conditions which may increase the efficiency of the Station work, we are first impressed with the multiplicity of duties devolving upon the Station workers. For the best results in scientific work, not only a peculiar aptitude is required, but the work can not be well performed if the worker's time is constantly interrupted, or if work is approached when one is mentally fagged. The higher class of scientific investigation requires a fresh mind, a condition to be attained for only a few hours per day. The work of teaching is pleasant and profitable to most

workers, and the greatest objection from the standpoint of the Station worker is that it breaks up the day. Even though the number of hours taken is not great, the day may be largely spoiled for investigation. From this standpoint, it would be better for the interests of the Station if the time of teaching on the part of the Station staff could be so arranged that some days of the week could be entirely free from such work, and given completely to investigation. This is one of the conditions which would probably increase the efficiency of our Station work. As it is, the work performed is apt to be far in advance of the published reports of the investigations. The preparation of bulletins and reports require in most cases considerable expenditure of consecutive time.

In the increase of usefulness of the Station, the development of our publications is also one of importance, and also the distribution of the bulletins. It is not only probable, but is known to be true, that a large portion of our bulletins reach people who do not make use of them. This is a condition which we hope to improve by making a classification of the names on the mailing list. At the same time, a classified mailing list is not a safe guide, because it so frequently happens that the very person who is the most interested in the bulletin is one whose line of interest is not indicated by his occupation. At present it would seem that without largely increasing the cost of distribution we must needs expect that a large part of the bulletins will not be used. We cannot expect to have results much greater than skilled advertisers who expect that only one person out of a great many will read their advertisements.

Another means of rendering our bulletins available to the public is through the medium of the Farmers' Institutes. These are good and form a supplement to the bulletin and printed reports; and are of value to the worker also, as they bring him in contact with the problems of the farmer in different portions of the country.

SUBSTATIONS.

During the past fiscal year only one substation has been in operation, that at Rockyford. In consequence of the refusal of the Department of Agriculture to countenance further expenditures, none has been made on the Stations at Cheyenne Wells, though investigations have been continued on the problems of the Plains.

THE DIVIDE SUBSTATION.

Since the last annual meeting of the Board, the affairs of the Divide Substation have been closed by the authorization of the Board. Our interests have been sold to Mr. W. A. Diebold for the sum of $650, of which $250 has already been paid. The re-

maining $400 bears interest at 6 per cent. per annum, and is to be paid within two years. The deed has been made out and is held in escrow by the First National Bank, of Colorado Springs.

THE SAN LUIS VALLEY SUBSTATION.

During the past year the affairs of this substation have been put on a better basis. The State Land Board had called for the return of the land to the State. It has been deeded back to the State Land Board by the authorization of the State Board of Agriculture. Prior to that time, our interests in the land had been sold to Mr. Oscar S. Wyland for $1,900, to be paid in four payments; the first for $400, in 1901; the second for $500 in 1902; the third for $500 in 1903; the fourth for $500 in 1904.

Mr. Wyland already had possession of the place and had crops in the ground in consequence of a previous understanding and we felt under obligations to treat with him. The bargain, howevver, was very advantageous to us. The first note is secured by a chattel mortgage on the crops and hogs. The other notes are secured by lease from the State Land Board, which is assigned to us.

The personal property remaining at the Station was of little value. This was left with Mr. Wyland, and is a part of the improvements which he purchased.

In addition to this, there was some personal property in the possession of P. A. Amiss, consisting of one team of horses, one wagon, and other property of which we could obtain no clear description and which might be difficult to identify. This property was sold to Mr. Amiss for $100 in cash. The money has been received and the transaction closed.

THE PLAINS SUBSTATION.

The Department of Agriculture having notified us that no further expenditure from the Hatch fund could be made at this Station, the plan of work has been along such lines as to cause no necessity for expenditure in connection with the Station itself. Mr. Payne has remained in charge, but with the title of field agent, instead of superintendent of the Station. The duty of the field agent is to investigate conditions in Eastern Colorado, and study the Plains with a view of finding out what has been, and is being done in agriculture, that may give promise of success. During the summer his trips have extended from the Arkansas river on the south, and nearly to the Platte on the north, and has covered a large portion of the country between these two points. He has lived in the house at the Station and made it his headquarters. The land at the Station was leased to J. W. Adams, who formerly worked at the Station, and as a condition of the lease, he was to take care of the fruit trees which were planted

near the house. The lease has been quite satisfactory and the place well cared for. The crop of sorghum which was grown produced a number of tons of forage.

As there is nothing to be done at the substation during the winter months, Mr. Payne has moved to Fort Collins, and the house has been rented for $4 per month, during the winter to a school teacher in Cheyenne Wells. The understanding is, however, that the Plains investigations shall be continued as during the past season.

As the situation now is at Cheyenne Wells, the buildings and improvements belong to the Experiment Station, but the title of the land is conditional. These buildings were partly put up by money from the Internal Improvement fund and from local sources. The buildings are good but the demand for them at that place is small. Cheyenne Wells derives its principal importance as the end of a division for freight trains, and as an eating point on the railroad. It is likely that dining cars will soon be substituted, in fact an order was promulgated that dining cars should be run from October 10. This action, however, has been delayed. It is only a question of time until the importance of the place becomes less, and the value of our improvements will be correspondingly decreased.

There is no doubt under our title regarding our rights to the improvements, if it becomes necessary to withdraw. As it now is, we cannot spend any of the Hatch fund, and there has been no provision to expend any of the other funds of the Board for that purpose. We shall get very little for the improvements when it becomes necessary to sell. The sum received will be far less than the amount which has been spent for them.

THE ARKANSAS VALLEY SUBSTATION.

In the case of the Arkansas Valley Substation, a large part of the land was leased to tenants for cash or for a portion of the crop. About twenty-five acres are retained under the supervision of the Station, an amount which could be attended to by the Superintendent and one man.

The total amount expended for the fiscal year ending June 30, 1901, was $1,726.43; the net receipts for the same time were $1,148.46, making a net cost of $577.97.

By action of the Board of Agriculture at the meeting in July and in accordance with a letter from Dr. A. C. True, it was decided to return to the State Land Board 160 of the 200 acres which had been put at our disposal for experimental purposes. With that authorization, the deed was transferred to the State Land Board. At the same time the Station also had twenty-four shares of stock in the Rockyford ditch; one of these shares had

been issued by mistake and the Board authorized its return to the Secretary of the Company. It had not been absolutely settled at that time whether the stock was to be returned to the donors in case of the abandonment of the Station or not. The records of the Board and especially those conditions upon which the Station was located at Rockyford would seem to indicate that it was an absolute gift.

The Board authorized the sale of the thirteen shares upon the condition that the purchaser should return the stock at any time of tender of the amount which he had paid. Since that time, the original donors of the stock have made claim that the stock by right belongs to them; that they gave it with the understanding that it was to be returned to them in case the Station was abandoned. The stock was given by individuals who gave from one to two or three or four shares each, and from the evidence now available, it appears the committee soliciting this stock made such representation to the donors. On the other hand, nothing has been found which would show that this was not one condition required by the Board; in fact, the records of the time would seem to indicate that the stock was to be in fee simple on the location of the Station. These donors will present their claims and perhaps be represented by a committee at this meeting of the Board. They will present such evidence as they may have which throws light on their arrangements with the Board at that time.

The improvements on the portion of the place which was relinquished were sold to G. W. Swink for $1,500. Mr. Swink had the original lease on this tract of land and relinquished it for the use of the Experiment Station in the year 1888. He made payment of one-fourth in cash and the remainder in approved notes bearing six per cent. interest. He has arranged that additional security should be given by the retention of the water stock for which he had bargained, until the whole transaction was completed. If it should be deemed best to return the stock to the original donors, the question will arise as to whether additional security should be given.

In a letter dated June 1, Dr. A. C. True, Director of the Office of Experiment Stations, having general supervision of the Hatch fund, wrote definitely that he must insist more strongly that the use of the Hatch fund for substations should be discontinued. This seemed to be a prohibition of the use of the Hatch fund for these purposes. This being the case, the question of the policy to be adopted toward the Substation at Rockyford arises. The Hatch fund, which has been the fund that has maintained this Substation, and during the time since its establishment, something like a total expenditure of $33,190.50 has been made. There have been receipts of $11,393.09, making a cost of $21,799.41. The net

cost of the Experiment Station has never been so small as during the past two years, when it amounted to less than $1,000 each year. In the years previous to that time when the ground was under the charge of the Superintendent, the cost one year was as low as $1,100 ($1,070.80), and as high as $2,900 ($2,890.66.)

There would seem to be three courses open to us:

1. To discontinue the work entirely.

2. To continue as a garden tract in an experimental way, as it was during the past year. This would require the maintenance of a man, a team and tools; a total expense including the salary of the Superintendent of not far from $1,800.

3. The use of the place only as a headquarters, retaining the improvements, house and grounds adjacent to it for the use of the Field Agent, permitting him to live there, and leasing the balance of the forty acres in such a way that we would not be responsible for any of the expense.

Under the ruling of the Department, it is still a question as to what extent it would sanction payment, except temporarily, of the Superintendent of the Station. In an official ruling some years since, the Department clearly stated its conception of the use of the Hatch fund. The Department recognizes the desirability of investigation in different portions of the State. It recognizes this as a proper charge upon the Hatch fund, where the work is of an experimental nature. Under this arrangement, it would seem possible for us to take up most of the investigations, or at least, part of them.

The work of the various sections is shown in the reports here appended.

Respectfully submitted,

L. G. CARPENTER,
Director.

REPORT OF THE ENTOMOLOGIST.

I have the honor to submit herewith the annual report of the entomological section of the Agricultural Experiment Station for the year 1901.

WORK WITH THE CODLING MOTH.

This insect occasions such heavy losses to fruit growers of Colorado each year that a considerable time has been devoted to a study of its habits and remedies. Much of the information gained had already been *published in one place or another but comparatively little has appeared in bulletins or reports of the Experiment Station. I have therefore thought it desirable to summarize the more important observations and conclusions in this report. They are as follows:

Life History.

Eggs of the spring brood begin to be deposited upon fruit and leaves when summer apples, like the Duchess, are about three-fourths of an inch in diameter. The last eggs of the brood are not deposited until late in July. The late moths of this brood have continued to appear in our breeding cages in cellars, to July 24.

The eggs, according to our observations, have been almost entirely upon the smooth surface of the apples, a small proportion, perhaps 10 per cent. have been found upon the leaves. Very few (3 or 4 per cent.) of the eggs under observation have failed to hatch, but there has been apparently a large mortality among the young worms. The time for eggs to hatch in the laboratory has varied between 6 and 8 days, with an average time of about 7 days.

The earliest we have found eggs on the apples at Fort Collins was June 9. Last year the first eggs were found June 19; the eggs of the first brood became most abundant about July 3, and summer eggs were most scarce about July 21. On July 27 an increase due to the eggs of the second brood was noticeable. Second-brood eggs were most abundant about August 12.

Larvae of the first brood began leaving the apples about Fort Collins in the spring of 1901, July 1; they were coming down most rapidly about July 21. By August 15 the larvae were coming in very small numbers and some of them were of the second brood

*Reports of Colorado State Board of Hort. for 1897, 1898, 1900, 1901 and Bull. 31, N. S., U. S. Dept. of Agr., Div. of Ent., p. 5.

as was shown in the fact that they began at about this date to live over till spring before pupating. The larvae of the second brood were most numerous under bands about September 10.

The time required for larvae of the first brood to develop varied between 12 and 24 days with an average time of 19 days.

The time spent spinning and pupating varied between 1 and 19 days with an average of 5.6 days. The greatest number pupated on the 4th day.

The time spent in the chrysalis by the summer brood varied between 10 to 21 days and the average time was 14 days.

For the entire cocoon stage the time varied between 12 and 29 days with an average of 20 days.

The time required to pass through these transformations at Fort Collins is no greater, according to our records, than at Rockyford, Canon City and Grand Junction where the summer temperature ranges considerably higher. The time spent in the complete summer life cycle has varied greatly but the average time has been almost exactly seven weeks.

Practically all the larvae taken at Grand Junction after August 10, and at Rockyford and Canon City after August 15, and at Fort Collins after August 20 live over till next spring before pupating. Occasional belated individuals are exceptions to the rule.

Moths from warm winter quarters may appear very early. Up to the time the orchards are in full bloom, we have found only about 10 per cent. of the moths hatched. At about this time they begin to appear rapidly.

The latest we have been able to rear moths of the second brood at Fort Collins has been September 16. The latest reported from other parts of the State by those who have assisted in the work have been as follows: Grand Junction, Sept. 12 (Silmon Smith); Canon City, Sept. 10 (R. J. Peare); Rockyford, Sept. 15 (H. H. Griffin); Palisade, Sept. 22 (C. H. Potter.)

Miscellaneous Notes on Habits.

While the second brood are generally thought to enter largely at the side of the apples because of the many worm holes seen there, our counts have so far indicated that 80 per cent. enter at the blossom end. Very many, however, enter by a very small hole, leaving no outside evidence, and then burrow to the surface on the side of the apple and keep the latter burrow open but not the entrance at the blossom.

Spring migration of the larvae is usually very light, but in a few instances they have come to bands in considerable numbers in certain orchards about Grand Junction during March and April.

Bands removed from a tree at 6 o'clock each evening and 7:30 each morning gave 414 larvae, 353 or 85 per cent. of which

came to the band during the night period and 61 or 15 per cent. came during the day.

By the use of bands we have taken from 17 per cent. to over 60 per cent. of the larvae on a tree as indicated by the number of wormy apples. The largest number of larvae from one band during the season is 1481. The tree was in a lawn and isolated.

Gathering apples daily from the ground gave us 16 per cent. of the worms from Duchess apples and 3.5 per cent. of the worms from Ben Davis trees as indicated by the number of wormy apples.

The saving of wormy fruit as the result of spraying twice with Paris green has varied in our experiment between 25 per cent. and over 90 per cent. The 25 per cent. saving was upon Duchess trees when the calyces of the apples had nearly all closed before the first application. The ninety odd per cent. was upon winter varieties.

LONG-TONGUED HONEY-BEES.

Bees from different parts of the United States were examined for the purpose of determining the range in length of the tongue of the honey bee. A progress *report on the work was made at the Annual Meeting of the Colorado State Bee-keepers' Association in Denver, November, 1901, and the work is not yet fully completed.

I have found that thrusting a bee into boiling water kills it in the best way to leave the tongue extensible for study.

I have been unable, so far, to find any evidence of a long-tongued strain of Italian bees, though several advertisers of "long-tongued" or "red clover" bees sent bees for examination. Tongues of the German or black bee have ranged between 23.5 and 25 hundredths of an inch; tongues of Carneolans between 25.5 and 26 hundredths of an inch; tongues of Italians between 24.5 and 26 hundredths of an inch, and tongues of Cyprians between 25 and 27 hundredths of an inch. Tongues of *Apis dorsata* preserved in alcohol measured between 25 and 26 hundredths of an inch. Tongues of bumblebees measured in comparison varied between 43 and 58 hundredths of an inch in length.

In all cases the distance from the base of the sub-mentum to the tip of the ligula has been taken as the tongue-length.

SUGAR BEET INSECTS.

Considerable attention has been given the past year to observations upon sugar beet insects on account of the importance which the sugar beet crop is assuming in Colorado.

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*The paper is printed in full in Am. Bee Journal, Dec. 12, 1901, and in Bee-Keeper's Review, Jan., 1902.

The beet army-worm *(Laphygma flavimaculata)* was not seriously abundant but attracted some attention in the lower Arkansas Valley over limited areas. Where the arsenites were used promptly they were successful in killing the worms. Mr. H. H. Griffin, Field Agent of the Experiment Station, reports that he found best success from the use of strong mixtures. He recommends using Paris green in the proportion of a pound to 50 gallons of water.

Nysius minutus, one of the false chinch bugs, was unusually abundant in the State last summer attacking a variety of plants upon both the east and west slopes of the mountains. One of its favorite plants is the beet. In places, many young plants were killed by them and Mr. Griffin and others at Rockyford state that they attacked mother beets that were being grown for seed so badly in places as to seriously injure the crop. Prominent among the cultivated plants attacked by this bug about Fort Collins last summer were beets, radishes, cauliflower and strawberries. The weeds most attacked were wild mustard, a tumble-weed *(Monolepis nuttallii),* yellow dock, lamb's quarter and Helianthus (sunflower). Many others were attacked to some extent.

Kerosene emulsion, whale-oil soap and Buhack were used in varying strengths for its destruction but almost without effect.

The accompanying cut shows the bugs about life-size on the leaves of yellow dock. (Fig. 1, Plate I).

The beet-louse *(Pemphigus betæ Doane),* was received upon the roots of beets from the vicinity of Rockyford and were sent by Mr. H. H. Griffin. The lice were found when the beets were harvested. The lice were sent as mealy-bugs because of the powdery covering to the body. Beets having the lice upon them were said to be spongy and of poor quality. Mr. Griffin thinks they occurred in several fields near Rockyford last year. It seems probable that this louse must occur upon the roots of some native plant in that vicinity and that it is transferring its attention to the beets.

MISCELLANEOUS NOTES.

Howard's Scale *(Aspidiotus howardi).* This is a near relative of the San Jose scale and was discovered by the writer some years ago on plum and pear trees in Canon City, Colo. The scale seems to have been the cause of the death of a few plum and prune trees near Canon City in one small orchard where it was first found and it still occurs in small numbers in that locality. I have not known of its occurring outside of Canon City until the past summer when the inspector of Delta county, Mr. H. E. Mathews, sent me specimens of the insect and later took me to an orchard where pears and plums, particularly the former, were badly attacked by it.

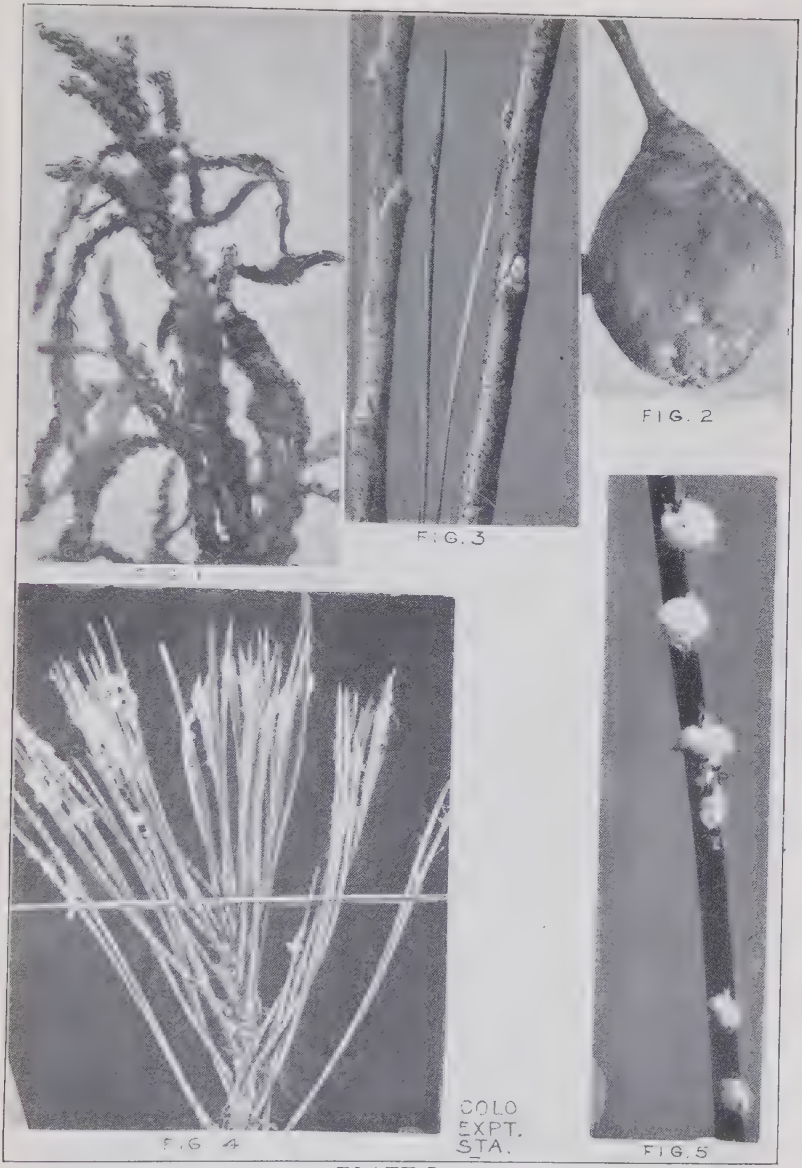

PLATE I.

Fig. 1. False chinch-bug (Nysius minutus) on leaves of yellow dock, nearly life-size. From photo by author.

Fig. 2. A young Bartlett pear, life-size, showing both young and adult scales of Aspidiotus howardi. The young scales are white. From photo by author.

Fig. 3. Two apple twigs showing eggs of apple louse, Aphis mali, and between these twigs two needles of Pinus ponderosa showing eggs of a species of Lachnus. Photo by author.

Fig. 4. A bunch of pine needles, natural size, showing the white waxy secretions of the lice. From photo by author.

Fig. 5. A pine needle much enlarged showing the masses of white waxy secretion covering the lice and their eggs. At (a) the eggs may be seen protruding from under the secretion. From photo by author.

FIG. 6

FIG. 7

FIG. 8

COLO. EXPT. STA.

PLATE II.

*Fig. 6. The thistle butterfly, Pyrames cardui, at plum blossoms; nearly life-size. From photo by author.

Fig. 7. A, peach leaf, life-size, showing cocoons of Plutella cruciferarum; B, one of the cocoons much enlarged showing its frail gauzy structure. From photos by the author.

Fig. 8. Plums, life-size, showing the punctures and gummy exhudations caused by the plum gouger, Coccotorus prunicida. The black specks on the plums represent the punctures which are made either for the purpose of taking food or egg-laying. Photo by author.

*A halftone from the same photograph was given in Agricola Aridus, Vol. 1, No. 3, p. 7.

Fig. 9. PLATE III.

Fig. 9. A cottonwood tree showing galls of Phytoptus mite on twigs. From photo by author.

Fig. 10. PLATE IV.

Fig. 10. Life-size galls of Phytoptus mite from twigs of cottonwood tree. Some galls may be seen developing from buds, others from the smooth bark of the twigs. From photo by author.

The orchard was examined June 12, at which time the young lice were just beginning to hatch. Pears containing lice were brought to the Station and the young continued to appear till August 20. The newly hatched lice are of the usual yellow color. They locate mostly about the blossom end of the fruit and the first scales are pure white. The older scales become darker and are usually sunken into the fruit. Sometimes there is a reddish discoloration about the scale. On raising a female scale it was often possible to find two or three lice and no eggs, but occasionally an egg or two or perhaps as many as three or four were also present. More often there were no eggs at all. So the lice hatch almost immediately upon the laying of the egg or, perhaps they as often hatch before the egg is laid.

The accompanying cut (Fig. 2) shows the scales, life-size, upon a pear.

The Apple Louse *(Aphis mali)*, continues to be a common and often very abundant pest upon the foliage of apple and pear trees after the middle of July or the first of August. During winter and early spring the black shining eggs are often seen in great numbers upon apple twigs. They are shown life-size, in Fig. 3. We have been unable to hatch these eggs when brought into the laboratory. Whether or not they hatch late in the spring upon the trees we have not certainly determined.

Woolly lice on spruce and pine. Two species (possibly one) of Chermes attack the leaves of spruce and pine in northern Colorado. The lice are very dark green in color having the appearance of black specks to the unaided eye. They arrange themselves along the leaves or needles and the females secrete large quantities of white waxy material to cover their bodies and also the clusters of amber colored eggs which they deposit in compact mass behind them. Each egg is attached by a thread. (See Figs. 4 and 5).

I have found kerosene emulsion or whale-oil soap of the ordinary strengths very effectual in killing these lice and their eggs.

The Thistle Butterfly *(Pyrames cardui)* was unusually abundant in many parts of Colorado last summer and attracted considerable attention from fruit growers, who were afraid it might be some insect injurious to fruit. The butterflies were abundant at blossoms of plum, cherry, apple and other fruit trees on both the eastern and western slopes. This insect is probably more beneficial than injurious as the larvae feed chiefly upon the leaves of thistles and other composite weeds and the butterflies assist in the fertilization of fruit blossoms.

The accompanying cut (Fig. 6, Plate II) shows a butterfly at plum blossoms.

The Cabbage Plutella *(Plutella cruciferarum)*. What seems to be a very unusual habit of this insect occurred in Colorado last

summer. Mr. H. E. Mathews, horticultural inspector for Delta county, sent me a quantity of peach leaves partly eaten and having attached to them large numbers of little white cocoons. Mr. Mathews stated that a portion of a young peach orchard had been very badly defoliated by this insect. In a few days the moths of the above named insect appeared from the cocoons and I was greatly surprised to find this eater of cruciferous plants attacking the peach. On visiting Mr. Mathews later I learned the particulars of the case which are as follows: The year previous a large amount of wild mustard had been allowed to grow in the orchard as a weed. Last summer clean cultivation was practiced and the moths of this insect, not finding the mustard upon which to deposit their eggs, turned to the only available plants, the peach trees. The accompanying cut shows the cocoons life-size, on a peach leaf and also a cocoon enlarged so as to show its gauzy structure. (Fig. 7, Plate II).

The Plum Gouger *(Coccotorus prunicida)* is abundant every year on the eastern slope where it is a very serious pest injuring the fruit of the red or Americana plums. The punctured plums are deformed, and gummy exhudations appear on the wounds made by the beetle for the purpose of egg-laying or taking food. The wounds made by the beetle and the exhudations are shown in Fig. 8.

If all growers of plums in a considerable area would agree on a year when they would all remove every stung plum from their trees between the middle and the last of July, they could in this manner almost exterminate the pest for a number of years.

I have found no signs of this insect on the west slope and it does no appreciable harm to European varieties of the plum.

Phytoptus Gall on Cottonwoods. Since coming to Colorado, some ten years ago, I have noticed the gradual increase in numbers of a small gall upon the twigs of the cottonwood. While the gall occurs generally over the State, it seems most abundant in the northern portion. Many cottonwoods in Fort Collins have these galls upon nearly every twig. They may form upon buds or upon the smooth bark as shown in the accompanying illustration. It is not uncommon to find trees as badly infested as the one shown in Fig. 9. Fig. 10 shows the galls life-size.

It will be difficult to apply remedies as the mites live over winter in recesses in the galls. The mites are reddish in color during winter and if galls are cut into at this season the mites may be found in great numbers in clusters. The galls do not have the effect to kill the trees as yet, and few limbs seem to have died from their attacks but they cause an unsightly appearance of the trees when the foliage is off.

C. P. GILLETTE.

REPORT OF THE CHEMICAL SECTION.

To The Director of the Experiment Station:

I herewith transmit my annual report regarding the work carried on by this Section of the Experiment Station.

No new work has been undertaken. The work set forth in the outline discussed at the January meeting of the Station Council has been prosecuted to the exclusion of all other work, no deviation having been made from the original plan.

There is at the present time a large mass of results which have not yet been published, but which are now in the course of preparation for publication.

The digestion experiments mentioned in the outline as having been at that time, namely, in January, far advanced, have had to be repeated and will probably be completed early in the fall, as will also the work on beeswax, which will be carried on by Mr. F. C. Alford.

There are no new needs of this Section which I shall present at the present time, as I believe you are fully conversant with the status of the section and its equipment.

Respectfully submitted,

WM. P. HEADDEN.

REPORT OF THE AGRICULTURIST.

The Experiment Station work in the Department of Agriculture has been somewhat varied during the year. Something has been done on each of the lines of work as planned at the beginning of the season of 1901. One bulletin, No. 66, on Tuberculosis, jointly written with the Veterinarian, Dr. G. H. Glover, has been published, and considerable material is on hand for other Station bulletins. It being the first year of the writer's work in this Station we have preferred to corroborate many of the notes before publishing them. Material is on hand for a bulletin on feeding Belgian hares, and some interesting results were obtained in feeding sheep and swine.

A large amount of data is accumulating from investigations with wheat and oats, especially with that part of the work which is being carried on at Monte Vista and at the College to compare the raising of grain at high and low altitudes. Published with the report is an account of our first year's work with macaroni wheats. We believe this variety of wheat will be quite valuable, especially in those portions of the State where irrigation water is either very scarce or wanting, and agriculture is carried on under scanty supply of rainfall. A number of varieties of macaroni wheat have been introduced from Russia by the U. S. Department of Agriculture which are being grown here in co-operation with the Department. Some of these varieties were collected on the high, dry steppes of Russia where they were raised without irrigation.

One of the most important lines of investigation which we have attempted is the work with grasses in co-operation with the Division of Agrostology. We publish herewith a detailed report of what was done the first year with a large number of varieties both in the grass garden and in a field which could be pastured. There is so much demand for information in regard to grasses which will either improve our ranges or be suitable for the making of pastures which can be irrigated, that we consider this line of work very important, and desire to give it much attention during the coming season.

The crop plats established last year gave some interesting results. Wheat which had been grown for a number of years at altitudes of 7,000 feet, shows a remarkable deterioration when planted here. The result was the same with a large number of varieties and it is interesting to know whether grain raised at high

altitudes is always apt to deteriorate sufficiently to produce very small crops when grown at low altitudes. On the other hand varieties of wheat obtained from Wm. Farrar, the great breeder of new wheats in Australia, did remarkably well, ripening a week or more earlier than the varieties which had been grown at home.

Two new brewing barleys, seed of which was furnished us by the U. S. Department, produced large crops here last season, and Russian spelt, so-called, really a variety of emmer was grown in sufficient quantity to supply grain for some feeding experiments which are now being carried on.

Although so much has been done by the Station with sugar beets during the past twelve years, we are now face to face with this new industry and should like to keep in touch with the commercial side of the question so far as our experimental work will be of value to farmers who are raising beets for the factories. The past season we raised sugar beets from which are to be selected mother beets for the production of seed. There is much demand also for information in regard to sugar beets for stock feed, so it is expected that beets will figure in the rations we adopt for experimental work in stock feeding, until we are fairly well acquainted with their effect when given in addition to other foods. A field experiment on the College farm was carried out with potatoes, the results of which are reported herewith in detail.

The Director distributed a large number of samples of sugar beet seed to farmers last spring. This seed was furnished by the U. S. Department for distribution. Very few of the farmers have reported the results obtained with the beets raised from this seed.

In addition to our work at home with feeding and cropping we have been able to accumulate some information from outside sources which will be of considerable value. Col. J. A. Lockhart, of Rockyford, who is feeding about 3,700 head of cattle, and is using beet pulp and beet molasses in great quantities, has agreed to furnish us his data for publication. The records are being kept in such a way that this material will be of great value. We visited Rockyford on two occasions and have obtained some photographs of the feeding plant and of the cattle which are being fed for market.

We have taken a series of photographs in many of the experiments carried out and consider them a very valuable part of our Station records as well as serving a most useful purpose for illustrating when we have data of sufficient value for publication.

My Experiment Station Assistant, Mr. A. H. Danielson, is thoroughly efficient. He has made his records very accurate and valuable, and his work in photography is of such a character that it is almost indispensable. Mr. Danielson has furnished the detailed reports of experiments with wheats, grasses and potatoes published herewith.

While not an employe of the Station, Mr. C. J. Griffith, who is assisting with the live stock work, is also a careful investigator and through his efforts we are able to publish material of value with regard to feeding live stock, and have accumulated data which will be useful for Station publications in the future.

FIELD EXPERIMENT WITH POTATOES.

In recent years it has not been possible to raise remunerative crops of potatoes in the vicinity of Fort Collins, and we carried on a field experiment to throw light on the difficulty if possible. While this experiment has been under way the Horticultural Section has also been working on the problem, and their discovery of the effects of a new disease on potatoes indicates, we believe definitely, the cause of our potato failures. It will probably not be advisable for us to continue the field experiments until such time as the Professor of Horticulture and his assistants have completed their work. Their investigations indicate that our soils have become so full of the fungus that causes the trouble, that it will be necessary to discover some general treatment which will destroy the disease producing spores, or to grow varieties of potatoes which will resist their attacks, or be immune.

Our field trial of last season is of interest, however, as it indicates that different varieties are affected in different degree. One of the objects of the experiment was defeated by accidentally getting the potatoes for seed which we had obtained from different localities mixed. We wished to compare seed raised at an altitude of about 9,000 feet in the mountains with seed of the same variety grown on the plains, but the two lots were not kept separate before planting so we are unable to report this comparison.

We purchased red and white potatoes in the market. The reds were probably Early Rose, and the white ones Mammoth Pearl, though the dealers could not give us the variety names. These were divided into separate lots. A part were treated and a part planted without treating, and parts were planted with and without fertilizers. The treatments given were with corrosive sublimate and formalin for scab, and the fertilizers used were raw bone meal and nitrate of soda. None of the potatoes produced large yields, but the red variety gave much better yields under the different treatments than was obtained with the white variety. The largest yield was 49¼ sacks per acre of marketable tubers, or a little less than 72½ sacks of large and small tubers.

The yields vary somewhat but it cannot be said that the fertilizers produced any increase. The treatment of seed with corrosive sublimate seemed to give a slight increase in yield of marketable potatoes, though the difference is small. The results of the experiment are given in the following table. The potatoes were

planted late, June 17, and harvested October 14. Lot No. 13 in the table was selected as free from disease. Lot No. 14 was affected with a dry rot (Fusarium) and was not treated. Lot No. 15 was affected seed with the injurious fungus (Rhizoctonia) but not treated. Lot No. 16 was affected seed treated with corrosive sublimate, and Lot No. 17 was affected seed treated with formalin.

It will be noted that the selected clean seed not treated, gave the largest yield of marketable potatoes. The diseased seed produced a poor stand of potatoes, or rather, many of the plants died from the disease after they came up, cutting down the yield.

Lot No.	Pounds Per Acre Planted	Variety Treatment Corrosive Sublimate	Pounds Fertilizer Per Acre	Market-able Per Acre	Not Mar-ketable Per Acre	Total Per Acre	Weight of 10 Largest Pounds	REMARKS
1	932	Red, Not Treated	None	2381	3075	5456	6.3	Decidedly Scabby
2	1207	Red, Not Treated	761 Bone Meal	2520	4360	6880	6.1	30% Scabby, balance free
3	941	Red, Not Treated	286 Nitrate of Soda	2130	3700	5830	7.2	Fair amount of scab
4	832	Red, Treated	None	4525	2835	7360	8.0	Free from scab
5	762	Red, Treated	477 Bone Meal	4925	2320	7245	7.25	Free from scab
6	754	Red, Treated	220 Nitrate of Soda	4615	2115	6730	7.00	Free from scab
7	814	White, Not Treated	None	2440	2460	4900	6.2	No Scab. Crackling of Skin
8	786	White, Not Treated	599.3 Bone Meal	2380	2190	4570	6.0	Free from scab
9	833	White, Not Treated	317 Nitrate of Soda	2360	2170	4530	6.2	Free from scab
10	878	White, Treated	None	2320	1915	4235	5.75	No scab. Few crackled
11	867	White, Treated	771 Bone Meal	2085	1965	4050	5.5	Free from scab
12	877	White, Treated	505 Nitrate of Soda	2380	1690	4070	5.75	Free from scab

Lot No.	Pounds Per Acre Planted		Market-able Per Acre	Not Mar-ketable Per Acre	Total Per Acre	Weight of Largest 10 Pounds	REMARKS
13	1019	Clean Seed, Not Treated	3733	2322	6055	10.5	Free from scab. No crackling skin. Outer skin peeling off.
14	641	Not Treated	1017	962	1979	6.00	Poor stand. Small potatoes.
15	1086	Not Treated	3666	2304	5970	9.00	Free from scab.
16	979	Corrosive Sublimate	2685	2549	5234	8.2	Free from scab, or small traces.
17	987	Formulose	2915	1889	4804	8.00	No scab. Less smooth than preceding.

PLATE V.

SHRINKAGE OF POTATOES.

Some of the red and white potatoes from the field experiment were stored in a root cellar, careful weights being recorded to determine the amount of shrinkage. There were two sacks of white potatoes and six sacks of a red variety placed on an old door which was used as a platform to keep them dry. The white potatoes were a late variety and having been planted so late, June 17, did not ripen. They were bruised and peeled badly from handling. They were weighed and placed in the cellar October 18, and were subsequently weighed December 14, and March 8 aproximately two, and four and one-half months after storing.

The following table gives the results. The lot numbers given in the first column correspond to the same numbers given in the table reporting the field experiment and are a key to the kind of seed, treatment and fertilizers used. It will be noted that the greatest loss of weight occured during the first two months, the average loss being 5.5 per cent. for that period, while it is only 7 per cent. for the whole time.

As would be expected the loss of the white potatoes which were green when harvested, was greater than the average. There is some variation in the shrinkage from the individual lots of red potatoes, but we would probably not be justified in stating that this difference is due to previous treatment of the seed from which the potatoes were grown, or to the fertilizers used.

SHRINKAGE OF POTATOES STORED IN SACKS.

Lot No.	Variety	WEIGHT Oct. 18 lbs.	Dec. 14 lbs.	March 8 lbs.	Total Loss lbs.	Per cent. Shrinkage in 4½ months
13	Red	101	96	94.2	6.8	6.7
15	"	100	95.5	94	6.0	6.0
16	"	1C6	102	100.5	5.5	5.2
17	"	117	109	107.	10.0	8.5
1	"	119	111.2	109.7	9.3	7.7
6	"	87	83.	82	5.0	5.7
11	White	85.5	80.5	78.5	7.0	8.2
12	"	88.5	83	81.5	7.0	7.9
Total		804	759.2	747.4	56.6	7.0

MACARONI WHEATS.

A Brief Report of the Varieties as Tested at the Experiment Station, Fort Collins, Colorado, 1901.

Through the importation and distribution of macaroni wheats by the U. S. Department of Agriculture, considerable interest has

been awakened in this class of grain. Macaroni wheats are considered drouth resistant varieties, and while there is objection in many parts of Colorado to any grain which produces beards, the macaroni varieties of wheat will undoubtedly take an important place in our agriculture, more especially so, perhaps, in the eastern part of the State where crops are raised without irrigation.

The varieties obtained from the U. S. Department were planted with a grain drill in plats 1-20 acre in size, using at the rate of 90 pounds of seed per acre. After harvest each plat was carefully measured and the yield per acre calculated. The stubble left on the field had an average height of 0.2 metres or 8 inches. The land used had been in grain the year before. The plats received one thorough irrigation June 26-27, and the precipitation for the growing season amounted to 10.53 inches, there being 7.47 inches in May, 2.35 inches in June and 0.71 inches in July. The weight per bushel of the grain harvested in nearly every case exceeded that of the seed planted. The table herewith gives the variety, the yield of straw and grain per acre, weight per bushel of that grown on the Station ground and of the seed received, and seasonal notes.

A report of these grains was made to M. A. Carlton, Cerealist of the U. S. Department of Agriculture. He writes as follows: "It is of particular interest to note how the weight of the grain which you have grown varies from the weight of the original seed, being in nearly every case greater than that of the original seed planted. The results as to yield per acre are considerably different in this case from what they have been in other states where trials have been made. In other cases the Kubanka has usually turned out the best, while in this case it stands only about fifth in the order of yield. The Gharnovka, however, which stands at the head in yield in this case is considered also a very good variety in south Russia."

The following additional notes not given in the table were taken of each variety:

No. 4277, Nicaragua. ("Triticum durum. This seed was obtained in Texas where the variety has been grown for a number of years. From its name it probably came originally from Nicaragua"). Was at about the right stage of maturity when harvested. Straw rather short. Grain of fair quality with somewhat smaller kernels than the others; small yield.

No. 5639, Kubanka ("Triticum durum, from Uralsk Territory, Russia. One of the best varieties of macaroni wheats in Russia"). This variety germinated and was above ground ahead of all others. A long strawed variety. The grain harvested was of less weight per bushel than the seed planted, lighter colored, longer kernels, harder and of greater vitreous luster. By grading

the grain threshed into two equal parts the heavier weighed 64 pounds per bushel.

No. 5642, Yellow Gharnovka. ("Triticum durum, from Ambrocievka, twenty miles northeast of Taganrog in Don Territory, Russia"). On July 9 considerable smut was noticed in this variety. The awns or beards were long and abundant. Grain darker colored, more plump, or not quite so shrunken, and of much greater vitreous luster than the original seed planted.

No. 5643, Gharnovka. ("Triticum durum, from the same place as the preceding number"). When harvested the awns stood at right angles to the heads making the grain somewhat disagreeable to handle. The grain is of the same color and luster as the original planted, but the kernels were decidedly smaller, with an increase in weight per bushel.

No. 5644, Velvet Don. ("Triticum durum, Chernouska of some reports, from the same locality as the above"). Heads with velvet chaff. Grain was lighter colored, of greater vitreous luster and longer kernels than the original planted.

No. 5645, Black Don. ("Triticum durum, Chernokoloska of some reports, from the same locality as the above"). Awns or beards were partly black. Grain much lighter colored, more plump and of greater luster than the original planted. After the threshed grain had been graded into two equal parts the heavier grain weighed 65 pounds per bushel.

No. 5646, Gharnovka, from Taganrog. ("Triticum durum, from Taganrog, Don Territory, Russia"). On July 9 a few heads of smut were noticed. The threshed grain of this variety is practically of the same appearance in every respect as the original planted, unless it be lighter in color.

TABLE OF COMPARATIVE YIELDS.

Number and Name	Grain Per Acre. Pounds	Straw Per Acre. Pounds. Stubble 0.2m High	Weight Per Bushel	Weight Per Bushel of Seed Planted	Average Height of Plants. Metres.	Date of Planting. April	Date Above Ground. May	Date of Heading. July	Date of Harvest. August
4277 Nicaragua	1078	3380	62.5	--	1.07	27	7	10	5
5639 Kukanka	1855	6133	62	64	1.57	26	4	2	5
5642 Yellow Gharnovka	1640	4980	63	60	1.44	26	8	5	5
5643 Gharnovka	1860	5730	63	62	1.37	27	8	5	5
5644 Velvet Don	1893	6476	63.5	63	1.47	27	6	3	5
5645 Black Don	1984	5930	64	63	1.40	27	5	3	5
5646 Gharnovka	1907	----	64	63	1.37	27	5	2	5

EXPERIMENTAL GRAIN PLATS.

Seven varieties of barley were grown in small plats of approximately one-tenth acre each, and one of these, the Hanna, was grown in a larger field trial of one-half acre. The results on the small plats are reported in the accompanying table.

The Bohemian and Hanna barleys were grown from seed furnished by the U. S. Department of Agriculture. The Bohemian came from Schurazenburg, Bavaria, and the Hanna from Kwassitz, Moravia, Hungaria. We could detect no varietal difference between these varieties. Both have the same season, and yielding power, and both show a tendency to drop the awns or beards at maturity which makes them less disagreeable to handle.

The Hanna is a famous European brewing barley. In a larger field trial of one-half acre it was drilled about three inches deep on April 22, using at the rate of 80 pounds seeds per acre. It received one irrigation on June 24, and was harvested July 25. The yield per acre was 1892 pounds, or at standard weight of 48 pounds per bushel, 39.4 bushels per acre. Our first season's trial indicates that this variety is well adapted to Colorado conditions.

The other varieties given in the table were from seed which had been previously grown at the College.

The oat crops are of some interest. Three new varieties are reported in the table. The varieties from Finland were a little earlier than the others, and one of them produced a large yield. There is a strong prejudice against black oats on the part of our farmers because the wild oats have become such a troublesome weed, and the seed mixed with other grain makes it less valuable. However, the black cultivated oat need not be mistaken for the wild variety, and while it might not pay to raise black oats for our markets, there is no good reason why a farmer should not raise them for his own use if he can obtain a superior yielding sort. The black oats raised from Colorado seed produced a much larger yield than any of the others which were raised under the same conditions, giving 71 bushels per acre, while the yield of the North Finnish variety was 60.5 bushels, and of our best white variety, the Silesian, was 52.4 bushels per acre. However, the Silesian oats planted on a larger area of alfalfa land, gave a fine crop. There was about eight acres in a field which yielded 497.5 bushels, or an average of 62.2 bushels per acre machine measure, and the oats weighed 37 pounds per bushel. On a selected and measured acre in this field the yield was 82 bushels by measure and 87 bushels by weight.

The Russian speltz reported in the table was grown from seed furnished by the U. S. Department. We also purchased 300

pounds of seed which was raised by William Lindenmeier near Fort Collins, and planted three acres of land with it. This field was irrigated June 24, and harvested July 27, yielding 181 bushels, machine measure. The crop weighed 5,386 pounds, which would make the weight per bushel 30 pounds, as it came from the machine only partially cleaned.

BROADCASTING VS. DRILLING GRAIN.

An interesting case of the relative effects of broadcasting and drilling the seed was noted on the experiment plats in 1901. On the plats where the effects of differing amounts of Nitrate of soda upon wheat and oats was being studied, the seed was broadcasted and harrowed instead of being sown with the grain drill.

The seed began to germinate fully a month after planting and then only a small per cent. came up. The plants which came up late did not have time to form sufficient root system to resist the dry weather which followed, and part of the oat plants dried up without maturing. On account of the late germination of the seed, the weeds got ahead of the grain and helped smother the plants coming up. This resulted in a total failure of the crop. Those plants which came to maturity showed absolutely no difference in growth on the fertilized and unfertilized plats.

B. C. BUFFUM,
Agriculturist.

SOME OF THE EXPERIMENTAL GRAINS—1901.

	Weight of Grain per Acre. Pounds.	Wgt. of Grain & Staw per Acre. Pounds.	Length of Heads. Metres.	Height of Straw. Metres.	Length of Stubble Metres.	Amount of Seed Planted per Acre. Pounds.	Date of Planting. April	Date Above Ground. May	Date of Heading. June.	Date of Harvesting. July	REMARKS
Barley, Beardless	1344	2688	.09	1.05	.17	95	27	5	25	26	Heavy heads; best hulls barley in the plots.
" Dakota Silver	1791	3582	.08	1.13	.19	95	27	5	25	26	More tall than preceeding.
" Black	1009	3183	.08	.85	.17	95	27	5	25	26	Bearded; Very short straw.
" Giant White—Salzer	1372	3828	.07	.97	.18	95	27	5	July 2	26	A late, tall, beardless, small-headed variety.
" Mansbury	2081	4951	.07	1.14	.18	95	27	5	June 25	26	A very handsome barley, tall and erect, bearded, six-rowed.
" Bohemian, from Schurazenburg	2294	5026	.12	1.06	.18	103	27	6	25	26	A two-rowed, bearded, brewing variety.
" Hanna, No. 5793	2266	4957	.11	1.09	.18	106	27	5	25	26	Similar to preceeding, long heads.
Oats, Russian, No. 2800	1289	4602	..	1.43	.18	103	27	7	July 9	31	Straw matures late.
" Black (Colorado Seed)	2272	6448	...	1.36	..	59	27	4	9	31	A late variety, slender straw.
" North Finnish, Black, No. 5739	1936	5808	.35	1.43	.25	77	27	6	2	26	An earlier variety; very coarse straw.
" Forneo Finnish, Black No. 5513	1450	3819	.34	1.40	.25	92	27	6	2	26	Much earlier than Selesian; some rust.
" Selesian	1677	4595	..	1.44	..	..	27	4	5	31	Sixty per cent. of heads ripe when harvested.
Speltz, Russian, No. 2959	861	3934	.08	1.30	.22	85	27	6	5	26	Straw matures from base; in the dough when harvested.
Rye, Prolific Spring	1570	4710	.11	1.36	.27	85	27	6	June 21	26	Heads well filled; fine stand.

PASTURE.

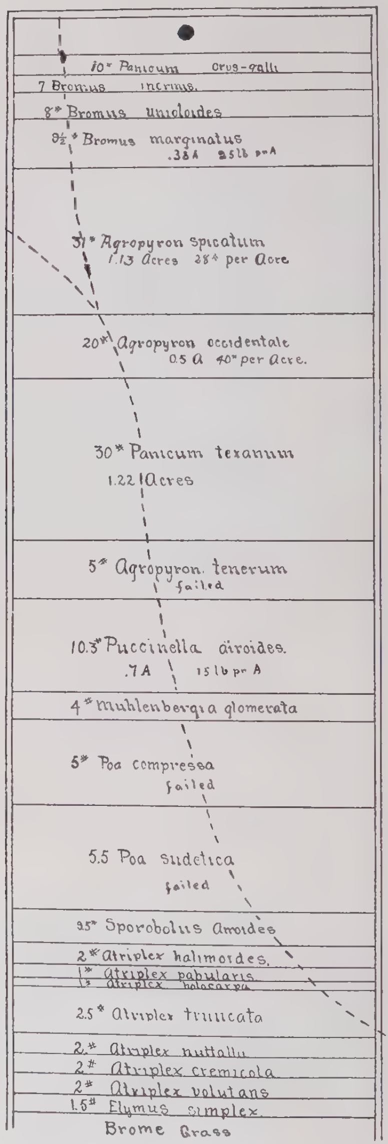

PLATE VI.
Dotted line represents an Alkali Slough.

PLATE VII.

Plat No. 99. Eragrostis neomexica(Mexican Crab Grass). August 22, 1901.

PLATE VIII.

Plat No. 92. Euchlaena Luxurians Teosinte. August 31, 1901.

A REPORT OF THE CO-OPERATIVE GRASS AND FORAGE PLANTS EXPERIMENTS WITH THE U. S. DEPARTMENT OF AGRICULTURE AT THE COLORADO AGRICULTURAL EXPERIMENT STATION, IN 1901.

BY A. H. DANIELSON.
Assistant Agriculturist.

In the spring of 1901 a great number of species of grass seeds were received from Prof. A. S. Hitchcock of the U. S. Department of Agriculture, to determine their adaptability to Colorado. Of these grass seeds, the larger quantities were planted in an eight acre field, in the middle of May, as field trial, and a small quantity of each was also planted in small plats in the grass garden about the first of June. In spite of the frequent rains during May and June very few made any sort of stand, and a great many did not germinate at all.

THE GRASS GARDEN.

A plat of ground was divided into small plats 8x10 feet, with 2-foot alleys between them. The ground had been in Brome grass for three years, and after the grass was started in the spring, was plowed deeply and again cross plowed. The plowed soil was then disc-harrowed again and again; harrowed with a common harrow several times and all the Brome grass roots dug and removed by hand. A heavy rain amounting to half a foot on May 20-23 was followed by several light showers until after another soaking rain the soil was well saturated, when on the 1st of June the seed was sown by scattering over the plats and raking it in well. During June frequent rains kept the surface moist, making unusually favorable conditions for the seed to germinate. The weeds of course proved to be more ambitious than the grasses planted, so beginning with July 1 the plats were weeded by hand and all weeds and plants except the variety planted removed. Part of the garden was watered with hose and sprinkler occasionally throughout the month.

It appears that slight differences in soil and method of planting have great influence on the germination and growth of grass seeds. The same seed which made good plants in the field failed to germinate at all in the grass garden. Different methods of planting, and early, late and fall planting will be tried, however, until we discover the right way, for we are determined to get a good stand with all the grasses and forage plants possible.

For convenience it has been thought best to divide the species

growing in the grass garden into classes: Those that made a good growth, a moderate growth, and those that made little growth or died out, and those which never germinated.

THE FOLLOWING SPECIES GREW WELL.

Plat No. 53. Panicum crus-galli—Japanese Barnyard Grass. Seed from Amherst, Mass., planted very thickly. July 10, up; July 22, one of the most luxuriant plants in the plats, entire plat covered and 20 inches high. Sept. 28, harvested; seed ripe and saved. Weight of cured hay from 80 square feet, 31.6 pounds, or at the rate of 8½ tons per acre. Weight of seed 2.5 pounds.

Plat No. 99. Eragrostis neomexica—New Mexico Crab Grass, an annual. Seed from Metcalfe, N. M. July 1, up. July 22, fine stand and very thick, 12 inches high. Aug. 31, the finest appearing grass in the plats; slender stems clothed with abundant foliage, has been heading for two weeks but seed is not yet ripe. Average height 36 inches, tallest plant 51 inches high. Oct. 4, yet unaffected by frost, seed ripe and shelling out. Oct. 19, harvested, weight green 22.9 pounds, seed threshed out 0.8 pounds. The seed does not ripen all at once and there is a great deal left on the stems which may ripen later when dry. (Shown in Plate VII).

Plat No. 92. Euchlaena luxurians—Teosinte. Seed from Texas Seed & Floral Co. June 14, well up. July 22, very thrifty, 16 inches high. Aug. 31, growing well, good stand, leaves resemble those of corn. Average height 30 inches, highest 47 inches. Seems very hardy, not injured by frost at all by Oct. 4. By Oct. 19 totally killed by frost and dry; harvested. (Shown in Plate VIII).

Plat No. 50. Bromus secalinus—(Cheat) (G. & L. Mont.) June 10, up. July 22, very good stand and thrifty, 4 to 12 inches high. Aug. 22, thrifty, close tufted mat, height 4-8 inches. Aug. 31, tops eaten and damaged somewhat by grasshoppers.

Plat. No. 68. Elymus Canadensis—Canadian Rye Grass from Shear, Colorado. July 2, up fairly well. July 22, fairly good stand, looks promising; 4-8 inches high. Sept. 15, a few heads have produced seed. March 11, 1902, the fall planting is coming up thickly, 1-1½ inches high.

Plat No. 56. Panicum milliaceum—Broom Corn Millet, from Potomac Flats, D. C. June 10, up. July 22, full stand, 8-4 inches high, just heading. Aug. 22, seed fully ripe and plants drying up, average height 17 inches. Sept. 21, harvested and seed saved. Weight of dry hay 1.6 pounds. Seed 0.7 pound.

Plat No. 88. Elensine coracana—African Millet, from A. B. Leckenby, Washington State. June 14, up. July 22, very good stand and thrifty, 12 inches high. Aug. 31, has been heading for the past two weeks but seed is not yet ripe; claw shaped heads on end of scape. Average height 16 inches, highest 24 inches. Sept. 28, harvested, seed has been ripe for some time. Weight of partly cured hay 17.4 pounds, seed 2.5 pounds.

Plat No. 59. Sporobolus cryptandrus—Drop Seed from Shear, Colorado. July 22, just coming through the ground very thickly. Sept. 28, a good stand but very short. Forms a sod, very caespitose.

Plat No. 54. Panicum texanum—Colorado Grass, Texas Millet, from H. L. Bentley, Texas. July 6, up. July 22, good stand at one end of plat. Better success in field plat.

Plat No. 51. Bromus unioloides, from M. W. Johnson Seed Co., Atlanta, Ga. June 14, up. July 22, good stand at one end of plat. Beginning to head, 8 to 12 inches high. Aug. 22, seed ripe, falling off; plants 15 inches high.

THE SPECIES WHICH MADE ONLY A MODERATE GROWTH.

Plat No. 70. Elymus ambiguus—July 2, above ground. July 22, up fairly well, 4-8 inches high.

Plat No. 60. Sporobolus wrightii—Saccaton, from Griffiths, Arizona. July 6, up. Sept. 28, a few good plants about 8-12 inches high.

Plat No. 55. Panicum bulbosum—Alkali Saccaton, from Potomac Flats, Washington, D. C. July 5, up. July 22, a few scattered plants but the greater part just coming up. Oct. 19, damaged considerably by grasshoppers.

THE FOLLOWING MADE LITTLE GROWTH OR DIED OUT AFTER COMING UP.

Plat No. 100. Cynocurus cristatus—Crested Dogs Tail, from I. W. Woods & Son, Virginia. July 1, up; died out later.

Plat No. 95. Boutelona oligostachya—Blue Grama, from Griffiths, Cochise, Arizona. Oct. 15, a few plants in evidence.

Plat No. 96. Calamovilfa longifolia—From Grand Haven, Mich. July 1, up; died out.

Plat No. 90. Agrostis stolomifera—Creeping Bent Grass, from Wood, Stubbs & Co., Kentucky. July 1, up.

Plat No. 85. Festuca arundinacea—Red Festuca, from A. B. Leckenlay, Walla Walla, Washington. June 14, up. Oct. 15, a number of plants, species uncertain.

Plat No. 84. Festuca rubra—Red fescue, from Peter Henderson, New York, July 1, up.

Plat No. 80. Festuca durinscula—Hard fescue, from Peter Henderson, New York. July 1, up.

Plat No. 76. Poa nevadensis—Nevada Blue Grass, from A. B. Leckenby, Walla Walla, Washington. July 1, up.

Plat No. 75. Poa laeviailmia—From A. B. Leckenby, Washington. July 1, up.

Plat No. 74. Poa trivialis—From Peter Henderson, N. Y. July 1, up.

Plat No. 69. Elymus glaucus—(G. & L. Mont.) July 2, up.

Plat No. 65. Elymus glabrifolius—Smooth leaved rye grass, from Texas. July 2, up.

Plat No. 64. Elymus virginicus submuticus—Short-awned rye grass, from A. B. Leckenby, Washington. July 2, up.

Plat No. 63. Agropyron spicatum—From A. B. Leckenby, Utah. July 2, up. (This species did much better under field culture.)

Plat No. 62. Agropyron occidentale—From Elias Nelson, collected near Wymore's ranch on the Big Laramie River, Wyoming, Aug. 24, 1900. July 2, up. (Under field culture this species made a good stand in places.)

Plat No. 49. Bromus richardsoni—Richardson's Brome Grass (G. & L. Mont.) June 14, up.

Plat No. 48. Bromus richardsoni pallidus—Richardson's Brome Grass, (G. & L. Mont.)

THE FOLLOWING SPECIES DID NOT GERMINATE.

Plat No. 98. Deschampsia caespitosa—Tufted Hair Grass. (E. Nelson, Wyoming.)

Plat No. 97. Dactylotenium australensis—Button Grass, from Potomac Flats, D. C.

Plat No. 94. Ammophila arenaria—Beach Grass, from Provincetown, Massachusetts.

Plat No. 93. Calamagrostis canadensis acuminata—From E. Nelson, Wyoming.

Plat No. 91. Alopecurus pratensis—Meadow Foxtail—From Wood & Son, Richmond, Virginia.

Plat No. 89. Beckmania erucaeformus—Slough Grass, (Griffith & Lange, Mont.)

Plat No. 87. Puccinellia airoides—From E. Nelson, Wyo. (This species made a fair growth under field culture.)

Plat No. 86. Festuca ovina—Sheep Fescue, from Nongesser & Co., New York.

Plat No. 83. Festuca kingii—King's Fescue, from A. B. Leckenby, Walla Walla, Washington.

Plat No. 82. Festuca heterophylla—Various leaved fescue, from D. Lendreth, Philadelphia.

Plat No. 81. Festuca thurberi—Thurber's fescue, from Shear, Colo.

Plat No. 79. Poa macrantha—Seaside Blue Grass, from A. B. Leckenby, Wash.

Plat No. 78. Poa wheeleri.

Plat No. 77. Poa lucida—Shining Blue Grass, from A. B. Leckenby, Wash.

Plat No. 73. Poa compressa—Canadian Blue Grass, from I. W. Woods & Son, Va. (This seed did not germinate either in field or grass garden.)

Plat No. 72. Poa sudetica—From Paris, France. No. 4334. (Not a seed of this lot germinated either in field or garden.)

Plat No. 71. Elymus condensatus—Giant Rye Grass. (G. & L. Mont.)

Plat No. 67. Elymus simplex—Alkali Rye Grass, from E. Nelson, Wyo.

Plat No. 66. Elymus macounii—Macon's Rye Grass, from E. Nelson, Wyo.

Plat No. 61. Agropyron tenerum—Slender Wheat Grass, from K. M. Iver, Canada.

Plat No. 58. Agrostis canina—Rhode Island Bent, from Peter Henderson, New York.

Plat No. 57. Agrostis alba—Red Top, from Nongesser & Co., New York.

Plat No. 52. Panicularia americana—American Manna, from E. Nelson, Wyoming.

A number of plats were planted with some commercial seed bought in the open market some years ago. Among these the following made fair success, particularly sand or hairy vetch *(Vicia villosa)*:

Orchard Grass, French Rye Grass, Italian Rye Grass, Common Crimson clover, Sand Lucerne, Bee clover, Sand or Hairy Vetch, Velvet Bean, Idaho Coffee Berry or French Pease, etc., European Flax, Johnson Grass.

In the fall of 1901 the grass plats were replanted by opening shallow furrows every six inches, leaving the ground between intact. This is to determine whether freezing the seed during the winter will cause it to germinate more satisfactorily. Early in the spring of 1902 the grass plats were again being replanted by opening furrows across those previously made. This is to see whether early planting is not more successful than late. We are determined to have a representation of all the species possible.

THE GRASSES AND FORAGE PLANTS UNDER FIELD CULTURE.

A field of over eight acres was planted to many species by drilling or broadcasting, to determine what the grasses would do under ordinary farm methods. A depression runs across the land through which runs the seepage from the fields above during the irrigating season. In course of time the soil in this depression has become strongly charged with alkali. The grass seeds were so planted that part of each plat was wet during the season while the balance was on high ground, not capable of being irrigated.

The seeds of the salt bush, *(Atriplex)* were planted in every possible manner on both wet, alkaline and dry land, but none germinated, at least this season. A wild millet *(Panicum sp.)*

PLATE IX.
Bromus Inermis (Brome Grass).

and a salt sage grows naturally in abundance on this land besides other weeds common on irrigated lands.

The land, which had previously been in a thin stand of Brome grass *(B. Inermis)*, was first disc-harrowed and then thoroughly harrowed with a common harrow. The seed was planted between May 10th and 14th by drilling it in with a common grain drill with grass seed attachment where the shape of the seed permitted, or broadcasted by first harrowing with the drill, sowing the seed and again covering by running over the ground with a drill. When all the seeds had been planted the surface of the soil was thoroughly compacted by running over it with a heavy iron roller. Very heavy rains between May 20 and 22, washed the land quite badly. Frequent rains the following month gave the grass seed a good chance to germinate—also the weeds. The latter became so thick by the middle of summer that the entire field had to be gone over with the mowing machine. In the latter part of summer the field was pastured by cattle.

No definite conclusions can, of course, be drawn from a single season's test, but we have received some valuable hints of promising species. The cultivated barnyard grass *(P. crus-galli)* is eaten greedily by cattle (it was almost dug out by the roots by them) and two species of Brome grass *(B. marginatus and B. unioloides)* seem to do better the first year even than *(B. inermis)*.

Panicum crus-galli—Japanese Barnyard Grass. Seed from Amherst, Mass. Sown very thick on 0.16 acre with grain drill at the rate of 64 pounds per acre, May 14. May 25, up. June 12, about 2-4 inches high. July 2, very good stand, 4 to 10 inches high. When pastured by cattle later in the summer it was very readily eaten by them.

Bromus inermis—Planted May 14 on 0.15 acre at the rate of 48 pounds per acre by broadcasting and drilling; drilled twice and broadcasted between the two drillings. June 12, about 1½ inches high; fairly good stand. July 2, very good stand in places.

Bromus unioloides—Rescue Grass, an annual, from M. W. Johnson Seed Co., Atlanta Ga. Seed planted May 14 by drill; drilled one-half of the land twice. July 2, fair stand in spots. July 18, heading or going to seed in places; 4-8 inches high.

Bromus marginatus—Shortawned Brome Grass. (Nees.) Sown May 13, by broadcasting; land harrowed with drill before and after sowing on 0.38 acre at the rate of 25 pounds per acre. June 12, fairly good stand, 1-2 inches high. July 2, very good stand in places, about 4 inches high. This species has made much better growth all around than B. Inermis.

Agropyron spicatum—From A. B. Leckenby, Utah. Sown by broadcasting on 1.13 acres at the rate of 27 pounds per acre; land harrowed before and after sowing. May 13, planted; June 12, very fair stand, 1-2 inches high. July 2, good stand in spots.

Agropyron occidentale—Collected near Wymore's ranch on the Big Laramie, Wyo., Aug. 24, 1900, by Elias Nelson. Sown by broadcasting on 0.5 acre at the rate of 40 pounds per acre, May 13. July 2, good stand in places, very slow to germinate and plants very scattered.

Panicum texanum—Texas Millet, Colorado Grass, from H. L. Bentley, Texas. Sown May 13 by broadcasting on 1.2 acres at the rate of 24 pounds per acre. June 12, just beginning to show above ground. July 2, fine stand in places. Oct. 23, has made considerable growth this summer and quite matted along the drill rows; plants average about 3 inches apart.

Puccinella airoides—From Elias Nelson, Wyoming. Seed broadcasted on May 11, on 0.7 acre at the rate of 15 pounds per acre. Seed very fine and small; screened twice but too full of straw to be drilled with grass attachment. Managed to drill a small part of the land. July 2, growing well in spots but there are large bare places. July 18, heading or going to seed; 8 inches high. Aug. 22, making fine growth in spots at north end; low densely tufted basal leaves; very slender fine culms.

Muhlenbergia glomerata—From A. B. Leckenby, Walla Walla, Wash. Broadcasted seed on 0.2 acre at the rate of 20 pounds per acre on May 11. June 12, coming up fairly well. July 2, very promising stand, about the best in the field.

Sporobolus airoides—Alkali Fine Top. Two lots of seed, from E. Nelson, Wyoming, and G. & C. Mont. Broadcasted May 10, harrowed with drill before and after sowing. July 2, making thrifty tufts of grass in places.

Agropyron tenerum—Slender Wheat Grass, from K. M. Iver, Canada. Seed like small oats. Planted with drill May 11. Total failure; never germinated.

Poa compressa—Canadian Blue Grass, from L. W. Woods & Son, Virginia. Sown with drill at different depths using small seed attachment, May 11. Did not germinate.

Poa sudetica—From Paris, France. No. 4334. Planted with drill, covering lightly, using grass seed attachment. Not a seed germinated.

Elymus simplex—Alkali Rye Grass, from E. Nelson, Wyoming. Planted May 10. Did not germinate.

ATRIPLEXES.

None of the following saltbushes germinated this year. They were planted with the drill where the seed permitted or otherwise broadcasted. They were planted by dropping the seed in a shallow furrow, by covering lightly and again deeply; they were planted on wet alkali soil, moist soil free from alkali and on dry land but none germinated.

Atriplex halimoides—Gray Saltbush, from Potomac Flats, Washington, D. C.

Atriplexx holocarpa—Annual Saltbush, from Potomac Flats, Washington, D. C.

Atriplex pabularis—Forage Saltbush, from Elias Nelson, Wyoming.

Atriplex eruncata—Utah Saltbush, from E. Nelson, Wyoming.

Atriplex nuttallii—Nuttall's Saltbush, from E. Nelson, Wyoming.

Atriplex eremicola—Desert Saltbush from E. Nelson, Wyoming.

Atriplex volutans—Tumbling Saltbush, from E. Nelson, Wyoming.

REPORT OF THE METEOROLOGIST AND IRRIGATION ENGINEER.

The work of this Section of the Experiment Station has been very largely the development of plans that have guided the work for a number of years.

The plans of work originally included a study of irrigation conditions of the whole State, or what was planned to be an irrigation survey. In connection with this an examination was to be made of the various valleys of the State, and the conditions especially regarding water and the use of water leading to a description of the valleys in detail.

The means at the command of the Section have been small so that the general purpose has been very much affected, and it has been necessary to take up some phases which would make no demand for funds. This originally lead to the seepage measurements on the streams, and these have been made during the past season, and carried on over hundreds of miles of streams. These particular investigations have made but small demands for funds, especially as aid has been given by the ditch companies in the different parts of the State, and others interested in the irrigation development. Other investigations which would require funds in addition to our equipment have had to be very largely set aside.

Meteorologicl observations have been continued. They are becoming of increasing importance. The object kept in view has been a study of the agricultural meteorology of the State, with each year's addition it becomes increasingly valuable.

These records are extensive and cover all phases, especially of the meteorology relating to moisture.

Respectfully submitted,

L. G. CARPENTER.

REPORT OF THE HORTICULTURIST AND BOTANIST

I have the honor to submit the following report of the Section of Horticulture and Botany of the Agricultural Experiment Station for the year 1901.

The work of the Department has followed along the lines laid down in the schedule, as closely as the available time would permit. Mr. Rolfs was detailed to investigate the cause of potato failures and he has devoted a large share of his time to this work. A number of preliminary experiments in treating seed potatoes before planting and of spraying the vines were undertaken. The results of these experiments together with field observations and laboratory studies prove that the failure of this crop in many portions of the State is due to root diseases; the one that is most destructive being a species of *Rhizoctonia*.

Potato plants affected with *Rhizoctonia* present different characteristics according to the nature of the soil, soil conditions and the extent of injury done to the plant by the fungus. Some of the conditions that are familiar to potato growers are, very large vines which may produce either no tubers, a few tubers, or an abnormal number of small tubers. In other instances the potato plant may be killed, thus reducing the stand materially.

A number of important facts new to science have been established and the experiments give promise of practical methods of overcoming these troubles.

The cultivation of potatoes on a large scale in Colorado is restricted to a comparatively few favored localities, which is no doubt largely due to the ravages of fungi. A practical method of combating these plant diseases will mean the saving annually of many thousands of dollars to the farmers of the State.

A report of progress on this work will be published in the near future in bulletin form. The work, however, is far from completion, consequently it will form one of our more important lines of investigation in the future.

The pea disease at Longmont was not as much in evidence this season as last, though it destroyed several fields. Our investigations show that the disease is caused by attacks of a root fungus, *Rhizoctonia* species, which if not the same is closely allied to the one that is so destructive to potatoes. The fungus is present in the soil when the pea seed is sown and there is no practical method of determining its presence except by its effect on the pea plants.

Now that we know what the cause of the disease is, experiments are to be undertaken the coming season to see if it can be successfully controlled or overcome.

Two trips were made during the summer to Delta county, to investigate a disease of apple trees which had attracted considerable attention in one locality. This condition was found to be due to soil conditions and water supply rather than to the attacks of fungi.

A good deal of attention has also been given to root rot of fruit trees that is present in orchards in many parts of the State. The investigation of this trouble will form a prominent feature in our future work.

A bulletin has been prepared on the subject of "Plant Diseases" which is soon to be published. This will contain a resume of the more important diseases of the year, and directions for treatment will be given where possible.

The investigation of the apple industry of the State has proceeded slowly, owing to the lack of time. However, some data has been secured which will be added to as time and opportunity permit.

The condition of celery, mentioned in my former report, known as pithy or hollow stem, was not as prevalent this year as last. Self fertilized seed from both sound and pithy stemmed plants was secured this fall. Should plants from either lot of seed show a difference in either direction, an effort will be made to improve the variety by selection and thus produce a strain of celery that will produce a large per cent. of sound plants.

Arrangements were made with the authorities of the New York Botanical Garden to work over the material in the College herbarium and classify the plants according to the present system of nomenclature. Accordingly the herbarium has been shipped to New York and an expert is now at work on it. It is gratifying to know that this work is now to be completed and that the Flora of the State is to be published in the near future.

Respectfully submitted,

W. PADDOCK.

REPORT OF THE ARKANSAS VALLEY SUBSTATION, ROCKYFORD.

Herewith is presented a summary of the work performed in the Arkansas Valley the past season:

The lines of investigation have dealt principally with the sugar beet, the cantaloupe and the tomato.

Leguminous crops have been tested for green fertilizing and forage and grasses for pasture purposes. The experimental orchard has been given due attention.

More than half of the time of the agent has been occupied in taking observations upon questions relating to the agriculture of the Valley, most of which had a bearing on the lines of work above enumerated. This part of the work has been less extended than it would have been were better transportation facilities at hand. For this reason most of the work has been restricted to the vicinity of Rockyford.

The Station land, with the exception of about 15 acres has been under lease to different parties.

The following embraces the lines of investigation with the sugar beet:

1. Means of securing a stand.
2. Success attained at different dates of planting.
3. What effect irrigation, applied at different times and in different ways, has upon the growth, yield and sugar content.
4. The use of green fertilizers, yard manures and nitrate of soda as fertilizers for the beet.
5. Note the growth of beets on alkali soil.
6. General and specific observations upon the depth of planting to secure best results.
7. Effect of hail upon the growth and maturity.
8. Observations upon insects and remedies and upon fungus diseases.

The following embraces the work with the cantaloupe:

1. Treatment of seed for blight.
2. The number of sprayings and the best time to spray for blight.
3. A verification of the work of former years.
4. Note the distribution and extent of the disease, also of insect pests.
5. Time of planting to get earliest maturity.

The following points have been studied with the tomato:

1. Propagation of the plants—what effect the use of different classes of plants may have upon maturity and production.
2. The effect of time of planting upon maturity and production.
3. The effect of fertilizers upon maturity, growth and production.
4. Test of varieties.
5. Pruning and training.

Many specimens of injurious insects have been sent to the

Entomological Department, and the Botanical Department has been advised of any fungus troubles.

Some general notes have been taken upon the spraying and irrigation of orchards and also upon the adaptation of fruits.

Full and complete record was kept of the lambs fed upon pulp for market.

The usual meteorological observations were taken and monthly reports forwarded.

Respectfully submitted,

H. H. GRIFFIN,
Field Agent.

Rockyford, Colo., Nov. 1, 1901.

REPORT OF THE PLAINS FIELD AGENT, CHEYENNE WELLS.

I herewith present the following report of work done at the Plains Substation and of the work done as field agent during the past year.

The Weather. A record of temperature, wind, rainfall and relative humidity of the air was kept until September 1, when the record of relative humidity ceased on account of the psychrometer being broken. I also acted as volunteer weather observer for the United States Weather Bureau until October 1, 1901. The usual April storm occurred causing serious losses to stockmen between the 1st and 12th of April. After the cold rains during the first part of April very little rain fell until the last of July. Several extensive prairie fires occurred during July. After rains began again there was plenty to keep the grass and crops in good condition until frost. June 11 to 15 was a period noted for storms all over the Plains of eastern Colorado. At Eads a regular tornado occurred; a saloon and school house were destroyed and several other buildings were damaged. The same day a windmill of A. Froelich, sixteen miles southwest of Kit Carson was wrecked by a storm, and the corral and stables of Mrs. A. Hinckley eight miles west of Kit Carson were destroyed by what was reported to be a cyclone.

About June 13, a sever hail storm visited the Vernon Divide, causing much damage to crops and to stock. I saw a frame house which had fourteen holes in the weatherboarding on the west side all made by hail stones during one storm. Some stones went through both weatherboarding and plastering. Animals happening to be exposed were killed.

Hot winds were quite common during June and July.

WORK AT THE PLAINS SUBSTATION.

Horticulture. The fruit trees made a good growth. The effect of the storm water upon the trees shows quite plainly even now. The trees nearest the place where the water comes into the orchard are much larger than those at the opposite corner. The storm water is carried to the orchard by means of furrows, and comes only at times of very rapid rainfall.

Apples. Two Duchess of Oldenburg bore about one-fourth bushel of fine fruit. We gathered from later varieties: Ben

Davis, one-half bushel; Winesap, one bushel; Utter's Red, thirteen fine specimens; Jeniton, seven specimens; Romanite, one-fourth bushel; Missouri Pippin, two and one-half bushels. The Missouri Pippin tree received some waste water from the house on account of having its leaves eaten off by grasshoppers. No wormy apples have been found among the specimens produced.

Plums. Six varieties fruited. The American Eagle plums were specially fine. The Weaver, Minor, Wolf, Cheney and Rolling-Stone were medium sized with fine flavor. From one Weaver plum tree we picked one-half bushel of fruit.

Cherries. Dry weather caused the cherry crop to mature imperfectly. About as many specimens were set as in 1900, but the fruits did not grow so large. Many developed only on one side of the stone. One English Morello tree bore heavily in 1900 and then died to the ground. It threw up a vigorous sprout this year which is believed to be above the bud. All standard varieties of cherries seem to do equally well.

Gooseberries. Both Downing and Houghton bore good crops. A few bushes died, apparently from some root disease. I find that nearly all who are raising gooseberries lose some bushes from this cause. Some distance below the crown the root turns black, while between the black part and the crown, the roots do not die for some time after the top has withered.

Apricots. Twelve Russian apricots set in 1899 are all vigorous. One fruit was set but was eaten by grasshoppers. It has been almost the uniform experience with the apricot on the Plains that it makes a pretty tree but produces but little fruit.

Peach Trees. Nearly all the peach trees survived the winter of 1901, and made a fairly good growth during the summer. They have not yet reached the bearing age.

Dewberries.. All the plants reported last year are alive, but none bore fruit this year.

Crab Apples. Nine of the ten crap apples set in 1899 are still vigorous, but none bore fruit.

Pears. Six trees set in 1899 are still alive. One of the trees blossomed but failed to set fruit.

Forest Trees. Of the forest trees reported in 1900, very few have been lost. All made a fair growth in 1901. We have grubbed out all but two rows of the Russian mulberries planted in the main field. These should be taken out next season.

Flowers. The Giant Cosmos showed a repetition of their growth and productivity of 1900. They did not produce a flower until after October 1. After that they flowered profusely until a hard frost. Ordinary frosts do not affect them.

FIELD CROPS.

Bromus Inermis. This grass grew well in the early spring, where it was not thickly set. During the summer dry spell it dried up entirely. It would have burnt at any time between June 20 and July 25. But when the rains came, it again revived and made a good growth. When last seen, October 25, it was still green.

Hagi. The plants grown in 1900 lived over winter and grew to be twelve to eighteen inches high this year. These are so thin on the ground that the plants are quite woody.

Sorghum. Only two varities of the several planted were harvested. These were Early Amber and Early Orange. The other varieties were planted later, after most of the moisture which fell in April had evaporated, so that none grew large enough to cut. Most of the seeds merely germinated.

It was the plan to do the work this year on a practical scale so as to make an estimate of the cost of production. Seven and one-half acres of Early Orange cane were planted, and twenty-nine and one-half acres were planted in Early Amber. On the plats receiving the same treatment very little difference could be noticed in the yield. It happened that the Early Orange was planted first and given one more cultivation than the Early Amber. The yields were as follows: Early Orange, 3,125 pounds fodder per acre; and the Early Amber, 1,470 pounds per acre. The cost per ton is about $2.20, or slightly less than $2 per acre for the sorghum fodder in the shock.

Different parts of the field furnished valuable object lessons on the value of culture at the proper time. But notwithstanding the losses from inability to cultivate at the proper time, the results show that fodder was put in the shock at a very low cost. Work done on this field is up to the average of the country. Hundreds of men lost entire crops by giving up and letting the weeds take their fields when a little labor spent in killing weeds during the dry time would have made them good crops.

Alfalfa. About three-fourths of the alfalfa sown in 1897 is dead. This did not produce enough to pay for cutting. Of that sown in 1899 only a little patch growing in a low place was cut.

INVESTIGATIONS OF EASTERN COLORADO.

The work done in 1901 was a continuation of the work of 1900 with the exception that less time was spent in collecting crop statistics. The greater portion of the time was given to looking for facts which would tend to explain the variation in results obtained in different localities by men of practically the same amount and quality of industry and intelligence.

A map accompanying this report shows the route traveled. 1,800 miles were traveled with a team over a territory approximately 96 to 144 miles. The territory studies include the three valleys of the Republican, the valleys of the Big Sandy, Rush Creek, Horse Creek, and Adobe Creek, and the drainage basins of all these streams.

The location of irrigation plants was noted and enough information concerning each was recorded so that we can get exact data later by correspondence in cases where it would have been expensive to get such information by personal observation. The leading interest of each locality visited was recorded, and men sought out from whom we might gain reliable information by correspondence.

Grain Farming. Concerning grain farming, but little can be added to the report of 1900 This is confined, with a few minor exceptions, to the divide between the South Fork of the Republican and the Arickaree, and that part of the divide between the Arickaree and the North Fork of the Republican lying east of the Sandhills. To these settlements with a few individuals near Thurman, Yale, Wallet, are confined the trials of grain raising now carried on in the territory studied. Outside of the two large districts the number who depend upon grain raising is becoming rapidly less each year. In those districts stock raising is becoming more prominent. A partial failure of wheat in 1901 caused many to feel like trying something else. Wheat was not more than a half crop, but corn on sandy land made a good crop wherever thoroughly cultivated. This was one of the years when careful, hopeful and industrious men were paid for their work and pains. A few who experimented were located and their results will be noted later.

STOCK.

Small Herds. By small herds we mean small bunches of cattle cared for by the owner or his family. The size of these herds ranges from a few head to four hundred head. As a rule feed is produced by the owner to feed the weak cattle through the winter and the whole herd through the stormy periods. Eastern Cheyenne, Eastern Kiowa, Northern Lincoln, Eastern Arapahoe, all of Kit Carson, Yuma and Washington counties are included in this, except the river valleys where larger bunches are kept. In this whole territory fodder consisting of sorghum, millet, milo maize or corn were produced. The variety of fodder raised seems to depend more upon the prejudice of the producer than upon the locality, as they are all grown more or less in each neighborhood. Sweet sorghum is becoming standard forage. It can be produced and put into shocks at a cost of about $2 per ton by

using ordinary machinery. It is likely that the cost can be materially reduced when the use of up-to-date machinery becomes more general. Even fodder production has not been found profitable upon adobe soil without irrigation.

Large Herds. These are found on land where crop raising has proved a failure, or in the hands of old time stockmen who are prejudiced against using the country except as a cattle range. The western part of Cheyenne and Kiowa, the southern part of Lincoln, and the northern part of Otero and Bent, and the valleys of the South Fork of the Republican and the Arickaree are, as a rule, occupied by large herds. The owners of large herds do not generally believe in feeding, and expect their cattle to hustle their feed in winter and summer. Severe losses during hard winters compel the belief that the time is coming when it will pay to feed cattle. This is especially true where the settlement has encroached upon the open range until it is all occupied to the point of being over-stocked. The time was when the valleys were left for the production of hay, but shortage of grass in the summer of 1901 compelled many rich meadows to be used as pasture. Old time cattlemen believe it is more profitable to ship in grain for use of their stock during storms than to attempt to raise fodder or grain by farming. I have been told by some of these stockmen that a man should be fined heavily if he should attempt to put a plow in the ground.

Improved Methods of Handling Stock. As the range becomes crowded, men must choose between feeding during the winter, going out of the business, getting absolute control of certain land, stocking it to its capacity, and then increasing the value of their stock, not by numbers, but by improvement in quality. As yet we have met only one man who is trying this plan. His young stock is now the third cross toward purebred and it is easy to recognize them when they become mixed with his neighbors' cattle.

Ranges. Losses incurred by stockmen in recent years make prominent the fact that we have some ranges that are fit for use the year round, and some which are safe only as summer ranges. The sandy loam soils and also the ordinary clay loam soils seem to be safe for use at all times of the year, but the adobe land has proven to be unsafe as winter range. In April, 1900, one cattle company lost fifty per cent. of the cattle put on a range where adobe soil predominated. Old stockmen claimed that the character of the soil was responsible for the loss. When the rain came the soil became a mass of very sticky mud, so that when the cattle walked each foot would soon become loaded with from ten to fifty pounds of mud. One of the riders who worked there told me that the course of the drifting herd could be easily traced by

the dead animals. The adobe country is excellent summer range, and large sections are used exclusively in that way, the cattle being taken either to the valleys and fed alfalfa during the winter or to other ranges which are safe.

MISCELLANEOUS OBSERVATIONS.

Fruit. Evidence has accumulated showing that plums, cherries and gooseberries can be grown without irrigation by carefully cultivating the soil.

A. E. Tabor, living ten miles southeast of Wray, has produced gooseberries on a commercial scale. His soil is a dark sandy soil. He cultivates carefully; but the efforts at the production of apples, peaches, pears, apricots and grapes without some means of supplying extra water during severe droughts are generally met with failure. However, fine fruits of all kinds have been raised during favorable seasons. For example, the Plains Substation produced some fine apples this year, but the rains happened to come just at the right time to save the fruit. An August drought would probably have caused most of the apples to drop.

The few orchards that are irrigated prove that there is nothing in the climate to prevent success if plenty of water is available when needed for the use of the trees. The places of John Rose, near Seibert; James Howell, near Flagler; John Speirs, near Robb; all show what can be done by irrigation. When I saw the places of Messrs. Rose and Howell, last August, the trees had been recently damaged by a severe hail storm. There were several bushels of fruit on the ground at that time, and what fruit remained on the trees was much damaged. Both these places showed fine fruit in 1900. At Mr. Speirs' last August, his grape vines were heavily loaded with fruit. He is raising considerable small fruit for home use. Peter Eckert, near Thurman, also had a fairly good crop of plums, grapes and cherries this year. Hail is the main source of loss when the trees can be irrigated.

Timber Claims. There is nothing to add to the report of 1900, as we have seen very few well kept timber claims this year. Those of Kursidim and Morris (photos of which are shown in bulletin No. 59) are the best that I have seen. These show signs of neglect this year.

Native Salt Weed. (Artiplex Argentea.) In the annual report of 1900, I recommended that the native salt weed found near the head of the South Fork of the Republican river, be tested as to feeding value and its distribution determined. Then I suggested that if it seemed to be a valuable forage plant, it should be distributed as widely as our means would permit. Three hundred pounds of the salt weed hay were sent to the Station Chemist, Dr. Headden, to be used in the feeding experiment. He reports that

sheep fed the salt weed hay all lost in weight during the test. A full report of the test will be published by the Chemical Department in the near future. In my travels during 1901, I found specimens of salt weed growing in nearly every locality in which adobe soil predominates. Especially if it is alkali soil. Recently I found a specimen near an alkali lagoon two miles south of Fort Collins.

Australian Salt Bush. During the year 1900, some plants of Australian Salt Bush were carefully cultivated in a protected corner of a town lot in Burlington, by Hon. T. G. Price. When I looked for them last summer, Mr. Price told me that they had all "winter-killed" during the previous winter. Dr. Headden informs me that Australian salt bush has proved to be an annual in Colorado, although it is a perennial in California.

Russian Thistles. I find quite a variety of opinion existing as to the value of Russian thistles as a winter forage for stock. Some claim that thistles are as good as alfalfa for forage, others contend that they are worthless. One man said he liked them for feeding during storms, because as soon as the storm was over the cattle would immediately leave the corrals and hustle for grass; while if millet, corn fodder or cane was fed, the stock would hang around the corral a day or two looking for feed. My own experience indicates that the last mentioned opinion strikes the happy medium and is probably an index to the true value of Russian thistles as forage plants.

Irrigation. Only a small part of the region studied this year is irrigated, and from the limited water supply now known, but little can ever be irrigated. No stream flowing through the territory furnishes enough water to make a large ditch pay, or for taking the water up on the divides, where the best water is usually found. Then, where there are good locations for irrigation on a small scale, it is so far from markets that most of the land must be used for raising cheap crops like alfalfa. The best possible use to which such locations can be put at present is as winter quarters for cattle which graze on the uplands during the summer. Most of the irrigated patches are now used in this way. A few use irrigation for making pleasant homes and supplying the family with fresh fruit and vegetables. On the divide it is possible to irrigate small gardens by means of windmills, and this is done by many.

Windmill Irrigation. The men who began with a small herd of cattle some twenty years ago, at first had too much water for their stock and so learned to irrigate a small garden. Later, when the herd increased so that it took the water as fast as the windmill would pump it, the gardens ceased to flourish. One calf was said to be equal in value to all the vegetables that could be grown

on a little garden patch. Many are now returning to the plan of raising a small irrigated garden. They say that the garden does not pay, but it is one of the luxuries which their present prosperity warrants.

Irrigation From Underflow Streams. Nearly all irrigation along the Big Sandy is by means of underflow. Tiling is used for getting the water out of the sand. Between two and three hundred acres are irrigated from the Big Sandy. We have records of many plants showing location, amount of land irrigated and kinds of crops raised.

Irrigation From Surface Streams. Nearly all the irrigation in the valley of the South Fork of the Republican is with water from the South Fork of the Republican river. Charles Milleson has forty acres which is sub-irrigated, and there are a few patches near him which are also sub-irrigated. There are fully three hundred acres irrigated in the valley of the South Fork. The Arickaree and its tributaries furnish water for the irrigation of nearly four hundred acres. There are about four hundred acres irrigated in the valley of the North Fork of the Republican river. The valley of Rush creek has about eighty-five acres irrigated. Horse creek and tributaries furnish water for the irrigation of about one hundred and sixty acres. Much of the irrigation water in the southern part of Lincoln county is secured from springs. The underflow of the Plains seems to come to the surface in many places along the head of Rush, Horse, Little Horse, Steels Fork and other creeks in that region. At one place I saw water flowing from a spring at the top of a hill. This spring furnished water for the irrigation of ten acres, and it looked possible to develop still more water from this source.

Storm Water. Nearly all the schemes for the use of storm water in irrigation have failed. However, there are a few people who depended on storm water and have succeeded in utilizing it. The Rosenkrantz ranch, where two hundred and fifty acres are irrigated from Dry Willow creek, a tributary to the Arickaree near the Kansas line, is one of the most successful which depends mainly on storm water. The reservoir was broken by a cloudburst in 1900, but it can be replaced at a small cost. James Howell's small plant near Flagler is a success. W. V. Erickson's plant was not yet at work when I saw it this year, as no heavy rains fell last spring to fill the reservoir. The future must test its value.

Men are going into irrigation at the points of the least resistance. Storage of storm water is a problem of the near future. As necessities arise for the use of storm water, it is likely that means will be found for retaining it on its watershed. This will be done in time wherever it will pay.

Loco. From March 20 to September 20, I took pains to col-

lect whatever information I could on the subject of loco. Map No. 1 shows the relative distribution of loco plants and is a part of this report. The evidence of stock men was unsatisfactory. The main points of agreement was that cattle, horses and sheep, become either crazy or stupid or both at times, and the witnesses think that eating some species of astragalus, oxytropus, sage or other plants common to the range cause the effects named. In all the region studied we found specimens of loco plants, but in some localities they were much more numerous than in others. There is some evidence showing that families of animals may be adicted to the loco habit; as a cow and all her calves, or a mare and all her colts. The evidence shows that loco plants can be killed by cutting them off below the crown. As the plants produce much seed this course must be persistently followed for a number of years, and thus eradicate them from the pasture. On open range which belongs to everybody, eradication of plants of loco is not a possible solution of the problem, as no one will work when reward is not sure. The subject must be given long and careful study before we shall be justified in giving an opinion upon it. We need accurate records of cases from beginning to end. Most of the evidence begins in the middle of the case with no available history of the animal affected before it was found sick.

Soil. During the year 1900 I took very few samples of soil, but observed the soil over which I traveled with a view of selecting samples later. In 1901 I made the taking of soil samples a part of my business. I took forty-five soil samples during the summer, making forty-nine samples in all. These are now stored for use whenever needed. Map No. 1, which is a part of this report, shows approximately the localities from which the samples were taken.

Soil Influence on Crop Production. One of the best illustrations of this is found when comparing Eads and Galatea. Near Eads is a small area upon which good crops of fodder are raised every year. At Galatea only 16 miles west of Eads, nearly all efforts at production of forage have proven failures. Eads and Galatea are located in small areas which are bountifully supplied with well water, but are surrounded by a country in which water is not easily found by digging. All the difference which can be seen is in the kind of soil used in trials at crop production. The soil near Eads is a dark sandy soil, while that near Galatea is a very stiff clay ,and may be classed as adobe.

Careful, industrious men have worked faithfully at Galatea, but failures compel them either to turn to stock raising or leave the country. Around the sand hills there is usually to be found a strip of dark sandy land where moderate crops of feed are raised every year while often the clay lands have been abandoned.

Difference in Climate. Examine the map and note the small

territory near Vernon between the North Fork of the Republican and the Arickaree which is east of the sand hills. This is the field of the most successful attempts at farming which have been made in the whole region of study. Crops average better there than on the divide between the Arickaree and the South Fork of the Republican. The soil certainly does not increase uniformly in fertility as we get further north. The people are of the same class. Rainfall as determined by local observers, is essentially the same. These three factors being so nearly equal, we must look outside the localities for an explanation of the differences. Note that north of the North Fork of the Republican river is a sand hill region about 20 miles wide. West of the Vernon neighborhood is another group of sand hills about 20 miles square. West of both groups, which almost join each other, near the source of the North Fork of the Republican river, is a region fully as large as the two sand hill regions which drains into the sand hills. Water is found in apparently inexhaustable quantities at a depth of 100 to 125 feet in the farming districts. I have noticed that heavy dews are frequent near Vernon in summer, and that hot winds are infrequent when compared to the Plains 100 miles south. Dews occur frequently on the next divide south of the Vernon Divide, but they seldom occur at Burlington and Cheyenne Wells. These facts indicate that it is possible that the success of the farmer on the Vernon Divide is due to the influence of the sand hills on the climate near them.

PROBLEMS WHICH CONFRONT THE SETTLER.

1. Means of combating insects, especially grasshoppers and potato beetles.
2. Garden irrigation.
3. Water supply and means of raising water from great depths.
4. Forage plants suitable for different localities and methods of producing them cheaply.
5. Destruction of prairie dogs on the public range.
6. Improvement, or introduction of small grain. (For a small district.)
7. The stock industry.
   (a.) Diseases affecting stock on the range and means of prevention and cure.
   (b.) Methods of handling stock suitable under new conditions.

Respectfully submitted,

J. E. PAYNE,

Field Agent.

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The Agricultural Experiment Station

OF THE

Agricultural College of Colorado.

STRAWBERRIES.

— BY —

C. S. CRANDALL and C. H. POTTER.

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Strawberries.

A prominent feature of the work of the Horticultural Section of the Station has been the testing of new varieties of fruits. Of the small fruits grown the strawberry has received a due share of attention. Five years ago a report was made (Bulletin 29) covering the varieties tested up to that time. Since then many varieties have been added to the collection. Some of these possessed merit, others were of no value. It is the purpose of the present paper to bring together the notes of the last five years, and record the estimates of value placed upon the different varieties under trial. It should be understood, however, that it is not the intention to recommend varieties for general planting. Observations on a particular variety continued through successive seasons enables us to rate with accuracy its value for this locality, and for the conditions under which it is grown, but we fully appreciate the fact that under different conditions of soil and surroundings its behavior may be quite different. Our best varieties may prove unprofitable in other localities, and some that are of no value here may take rank among the best when grown under different conditions.

Varieties of strawberries as well as of other fruits are largely local in character, and the best for a particular locality must be determined by trial in that locality.

Cultural directions for strawberries were given in Bulletin 29, but as the edition is exhausted and as inquiries on various cultural points are frequently received, it is thought best to again touch briefly upon the more important features of strawberry management.

SOIL.

The strawberry can be made to grow on a great variety of soils, but it is easier to manage and reaches a better development on light loams than on heavy clays. A soil improperly drained, where water may stand for long periods, is entirely unsuited to this as well as to other fruits, and a very heavy clay is to be avoided if possible. A sandy loam of good fertility will produce earlier fruits than a heavy soil, it is easier to work, can be worked sooner after rains, and is in general more satisfactory. In many places along our streams there are broad stretches of bottom lands, sandy in texture and rich in humus, which, if well drained, are admirably adapted to strawberries.

It is best with any soil that it be cropped for one or two seasons before planting with strawberries, and preferably with crops that demand clean culture. It is of the first importance that the

land be free from weeds and in loose, mellow condition. It is not good practice to plant on freshly turned sod; such land should be used one season for some hoed crop, which will leave it in good condition for strawberries.

For most soils deep plowing is to be recommended. There is an advantage in inducing the plants to root deeply. The deeply loosened soil holds more water, and the plants are less liable to injury during scarcity of water.

LOCATION.

The location for strawberries should be chosen with particular reference to irrigation. Land lying nearly level is to be preferred, but gentle slopes can be utilized by planting on contour lines, or in such manner that the furrows for irrigating have only sufficient fall to move the water slowly without washing the soil.

Great care snould be taken to have an even surface. High points must be lowered and all depressions filled, so that the furrows will nowhere overflow and flood the rows. This can be best accomplished by the use of a simple box scraper made of plank. Generally it is a good plan to plow deeply in the fall. If the soil is heavy and inclined to be lumpy it may be best to harrow at once after plowing, but with lighter soils this is not necessary. In the spring plow again and harrow until the surface is finely pulverized.

FERTILIZERS.

Colorado soils are yet new, they have been cropped for only a few years, and the question of fertilizers has not yet demanded much attention.

Locally their need is being felt, and no doubt the time will come when the problem of the maintenance of soil fertility will be as important here as it is now in the older agricultural districts. The intelligent application of fertilizers calls for inquiry into all the conditions surrounding, not only the locality, but the particular piece of soil to which the application is to be made. It is essential to know something of the physical condition. Is it heavy clay, or light sand? Is it loam or gravel? Is it level or sloping? Is the substratum rock or impervious clay, or is it porous gravel? Is the soil deep or shallow? Well drained or inclined to hold the applied water? Knowledge on these points is gained by observation and examination, and they are all important, because they have a direct bearing upon the kind and quantity of fertilizer, and upon the time and manner of its application. As supplementary to a knowledge of the physical condition of the soil, it would be well to know something of its composition as shown by chemical analysis. While I do not believe chemical analysis can be taken as an index of the producing power of any particular soil, it is valuable in connection

with a careful study of physical characters, in leading to the intelligent application of needed elements. Chemical values are potential, and while an analysis may accurately give the percentages of the various elements present, it can not tell with exactness what quantity of each essential element is in condition for immediate use as plant food. It is hardly possible to analyze the complicated processes that are taking place in the soil, converting complex inactive compounds into simpler forms ready for use in building up plant tissue. These processes are constantly in operation; they are less obvious and less known than many phenomena that are given prominence, but they are none the less important factors bearing upon the productiveness of soils.

An examination of several analyses of Colorado soils shows that they are rich in all of those elements classed among the inexhaustible soil ingredients, and that they also contain good percentages of the exhaustible elements which are so necessary to plant growth—nitrogen, phosphoric acid, and potash. It may be that much of the wealth of plant food shown by these analyses is not in an immediately available condition. If this be the case, what is the remedy? I may answer that the remedy may be sought in thorough cultivation and in an increase of humus by the addition of stable manure or by plowing under a soiling crop. Increase in the percentage of humus is important not only for its direct value as plant food, but for its influence on the physical condition of the soil, and for its action on other soil compounds. It makes clay soils less compact and increases the compactness of sandy soils; it increases the capillarity of the soil, thus bringing up to the roots food-laden water from below; it acts as a sponge to hold water in the soil, and it is a storehouse of nitrogen.

The strawberry is a gross feeder and to reach perfection demands a rich soil. I believe any soil intended for this plant will be benefited by a liberal application of stable manure, preferably that which has been rotted by composting. Our practice has been to apply a heavy dressing in the fall. This is plowed under and the surface harrowed down. Then water is applied until the ground is thoroughly soaked. In the spring we plow again and thoroughly pulverize the surface. The soil is then loose and moist at time of planting.

The principal objection to the use of fresh stable manure is that it is likely to carry with it many seeds of troublesome weeds. These seeds germinate or are in various ways killed during composting; then, too, the rotted manure is more readily incorporated with the soil and is more quickly available to the plants.

TIME TO PLANT.

In our practice at the Station we have had the best success from spring planting, and believe that in general it will be found

best for Colorado conditions. In regions where the rainfall is greater and where cloudless days are less common, planting in August is practiced successfully by many, but the practice is by no means universal, and most growers who plant large areas prefer to plant in the spring.

Here there is often trouble in obtaining the desired number of well-rooted young plants early enough so that when transplanted they may become well established before the end of the growing season. The prevailing bright suns during August are trying to newly set plants, they are liable to wilt and be severely checked, even when care is used to apply water frequently. Stronger plants are obtainable in the spring, the ground is then moist and the air cool, they are checked but little and make a strong growth from the beginning.

If potted plants are used, the objection to August planting has not the same force, but the expense of potting is such that the practice is not to be commended, except possibly in a small way for the home garden.

METHODS OF PLANTING.

Two systems of planting strawberries are in use. The hill system, and the matted row system. In hill culture the rows may be two and one half or three feet apart, with plants twelve inches in the rows. No runners are allowed to form, the plants are kept distinct and are encouraged to make the strongest growth possible. The fruits produced are large, but the labor involved is considerable and the system is only suitable for small areas. The matted row system is in almost universal use for commercial plantations because the labor is less and the quantity of fruit greater. The plants are set from eighteen to twenty four inches apart in rows three and one half or four feet apart. To enable the plants to become well rooted, it is best to remove all runners until about the first of July, after which the runners may be allowed to root until a space eighteen inches wide is filled. The ideal matted row should have a width of eighteen inches with the plants distributed at about equal distances, five or six inches apart.

Some varieties produce runners so freely that it may be necessary to thin them somewhat to obtain the best results.

In transplanting, care should be taken that the roots do not become dry. It is a good plan to carry the plants in some vessel containing water and to distribute only as fast as they can be planted. In planting, a spade or dibble may be used. The roots should be spread out fan shaped and care taken to plant at the right depth. If planted too deep the crowns are liable to rot, and if not deep enough the roots will dry out, either being fatal to the plant. The earth should be well firmed about the roots and the surface left level.

IRRIGATION.

An ample supply of water is essential to success with Strawberries. The plants need it in quantity throughout the season and particularly while maturing fruit. No garden plants more quickly suffer from lack of water, and none respond more readily when it is properly applied. It is our practice to make a shallow furrow close to each row of plants as soon as they are planted and run water at once, even though the soil be moist. It settles the earth about the roots, is an insurance against possible dryness, and gives the plants a vigorous start.

It may happen after an exceptionally open and dry winter that the soil in spring is very dry. We may then proceed in one of two ways; either irrigate first, and then, as soon as the ground can be worked, plow and prepare for planting, or the land may be prepared first and furrows made in which water can be run as the plants are being set. Do not try to set the plants in the furrow, in wet soil, but plant on the borders of the furrow and so plan that water may soon after reach them. The first plan is the best, but it sometimes happens that the ditches are not supplied with water early enough. In that case the ground must be made ready and the planting delayed until water is available.

Care should be taken in running water that it be confined to the furrows and not allowed to flood the rows. It is better to run small streams for long periods than to try to hasten matters by running too much water. To insure an even, constant flow, we make a lateral across the ends of the rows and supply the furrow for each row through a short piece of one inch pipe which is imbedded in the bank of the lateral. This is safer and easier to manage than breaking the bank of the lateral for each furrow, especially in soils that are inclined to wash.

As to frequency of irrigation, no definite rule can be given; it must be determined for each particular piece of ground. Some soils may require twice as many applications as others. Study the condition of the soil and the appearance of the plants, and govern the water supply by the indications there found. A thorough irrigation late in the fall, just before the ground freezes, is an excellent protection against a possible dry winter.

TILLAGE.

Thorough cultivation during the first season can not be too strongly urged. It conserves moisture, promotes the growth of plants, keeps the weeds down and is in every way beneficial. The after success of the plantation depends much upon the care given during the first months after planting. Cultivation should be continued until October, but after the runners commence forming new plants the space cultivated must be narrowed and the hoe used

among the plants. Train the runners within the limits of the matted row, and when enough plants are formed cut those that encroach upon the space between rows.

There are differences of opinion regarding spring cultivation of an established bed. Some allow the mulch to remain, and hold that it is best not to disturb the ground until after fruiting. Others remove the mulch and cultivate the spaces until fruit begins to set. We find it best to remove the mulch, because it interferes with furrowing for irrigation. The spaces are cultivated after each irrigation, until near the fruiting season, then furrows are made so that water can be applied as needed, and the bed is not further disturbed until after the fruit is picked.

MULCHING.

Mulching is regarded as an essential to success. It protects the plants from the ill effects of freezing and thawing consequent to the extreme daily range of temperature common during February and March, and it retards blooming, thus diminishing the danger from spring frosts. A light cover answers every purpose. Heavy mulching is unnecessary, and if too heavy may injure the plants. Hay, straw, coarse manure, leaves, and cornstalks have all been used as mulches. Marsh or swamp hay, if free from weeds, makes an admirable mulch, but often is not obtainable. Wheat straw is better than oat straw, because usually threshed cleaner, but with either kind it is safer to use old rather than new. If the bed to be mulched is exposed to strong winds, it will be necessary to use brush or poles to prevent the straw blowing from the plants. Coarse manure is usually objectionable as a mulch, because of the weed seeds it is likely to contain.

SELECTION OF VARIETIES. POLLINATION.

Varieties of strawberries are many, and choice of kinds should be made with reference to the proposed disposition of the fruit. If for home use or home market, high flavor in connection with size and productiveness would govern the choice, but if for shipment to distant markets, firmness and long keeping would be of first importance, and must be given preference over other good qualities. No variety has all the desirable qualities equally developed, that is, the ideal, all-purpose berry has not yet been produced, and the best we can do is to choose the nearest approach to an ideal for our specific purpose.

Choice can not be made from reports upon a particular variety for some other locality, but must rest upon actual trial in your own locality, because, as we have already remarked, the same variety may behave very differently under unlike surroundings. For commercial growing it is best to confine the attention to few varieties, and be certain before planting largely that these varieties

are adapted to your purpose and conditions. A succession to prolong the season may be desirable, but generally it will be found that the varieties intermediate in time of ripening prove most profitable. It is well enough to try novelties and new introductions in a small way, but never invest largely until their merits for your locality have been tested.

Choice must also be governed by blossom characters. Varieties are of two classes; those having perfect flowers, or in other words bearing both stamens and pistils, and those having pistillate flowers, or bearing pistils only. Some of our best varieties come under this latter class, and their ability to produce fruit depends entirely upon the proximity of other pollen producing varieties. Among the varieties bearing perfect flowers there is a wide difference as to pollen production; some have few and weak stamens and do not produce enough pollen to perfectly fertilize their own pistils; others have a normal complement of stamens with well filled anthers that have pollen to spare.

The strawberry is so commonly grown that it may seem unnecessary to dwell upon flower characters, but so many mistakes arising from inattention to these essentials have come under my immediate notice that the remarks upon the subject appear warranted.

If a pistillate variety has been decided upon, the question as to what proportion of the variety to be used as a pollenizer is necessary at once arises. On this point there is difference of opinion among growers. Some say four rows of the pistillate variety to one of the pollen producer, others would plant the two in equal quantity. I have found that two rows of the pollenizer alternated with four of the pistillate variety gave good results, but it may be as well to use them in equal proportions, particularly if both are desirable varieties.

A further point in reference to pollination may be touched upon here. Definite experiments upon apples, pears and plums have shown that some varieties are either wholly or in part self-sterile, that is, the pollen of a particular variety may be incapable of acting upon the pistils of that variety, or may act so slowly and imperfectly that the variety is unproductive. No definite experiments have been made upon strawberries, but observation leads to the suspicion that some varieties are, at least in some degree, self-sterile. If this be true, the obvious remedy is the same as recommended for the other fruits, namely, to mix varieties, not planting very large blocks of a single variety.

Fertilization in the strawberry is accomplished by insects, largely by bees, and if several varieties are near together the pollen is sure to be so distributed that the maximum of fruitfulness will result. Even if all varieties chosen for planting are strong pollen producers, we may infer from experiments upon other plants that

there would be advantage in planting in alternate narrow blocks in order to facilitate interchange of pollen, for it has been shown that some plants, although perfectly self-fertile, derived advantage from the use of foreign pollen.

A further point to be considered in choosing varieties to be planted together, is the time of blooming. To be of advantage to the pistillate variety, the pollen producer must bloom at the same time, and the same would be true if aiming at mutual advantage from cross-fertilization between perfect flowered varieties.

PICKING THE FRUIT.

If the berries are to be shipped some distance, it is important that they be picked at just the right degree of ripeness, not too green nor yet fully ripe. This can only be learned by experience.

The calyx with a short piece of stem should always be left attached to the fruit. Growers should watch that careless pickers pay attention to this point, as it is essential to the keeping quality. Berries detached from the calyx should go with the over ripe fruit and buttons, and these shoul l never be mixed with good marketable berries, because they take from the value of the whole. Careful grading requires extra labor, but it is profitable. The grower who attends to it can establish such a reputation for his fruit that it will be always in demand, even at advanced prices. It is the common fruit that is always over-abundant in the markets. Choice fruit is, as a rule, scarce and seldom seen on the market in quantity equal to the demand.

After the fruit is all picked, the spaces between the rows should be cultivated and the rows cleared of all weeds by hoeing. Cultivation should be continued until October, and water should be applied as often as is necessary to promote vigorous growth. Good care will induce the formation of fruiting crowns, upon which the success of the next crop depends.

DURATION OF PLANTATIONS.

In our experience two years is as long as a bed can be maintained with profit. The first year of fruiting will give the largest fruit, the second the greatest quantity, then vigor diminishes; the rows are too crowded to admit the growth of new plants, weeds multiply and are hard to control; for these reasons it is best to plow up the bed immediately after the removal of the second crop. A new bed should be set each year and an old one plowed up. Following the plowing of an old bed, the land should be used for one season for some other crop, or it is possible to meet good results by sowing with some soiling crop as soon as plowed, this to be turned under in the fall.

Many eastern growers find greatest profit in the practice of taking but one crop. The plants are set in August, fruited the next

June and then turned under, but here in the west I believe it best to take two crops.

DESCRIPTION OF VARIETIES.

Annie Laura.—bisexual. Originated with J. F. Beaver, Montgomery county, Ohio.

The plants are of good size and vigor, forming sufficient runners and young plants. The leafstalks are short and stout, the leaflets are medium to large, broad, rather thin, coarsely toothed, pale to dark green in color. The bloom is not abundant, the flowers are very large, the petals are often over five in number, the stamens are large and well formed.

The berries are large, short, blunt-conic to oblate, scarlet, with glossy surface, slow in coloring at tips, inferior in quality and yield.

First bloom 19th to 22d, and the last bloom about the 28th of May. First ripe berries about June 19th, and the last picking July 12th.

With us this is a poor variety.

Aroma.—bisexual. Originated with E. W. Cruse, Leavenworth, Kansas.

The variety is a healthy, vigorous grower, of medium habit, setting runners very freely. The leaflets are large, broad-oval, closely notched, dark green in color. The trusses are medium to long, stout, upright, with but few branches, and these produce but scant bloom. The flowers are large, the petals are often over six in number, and the stamens are well formed. The calyx is sometimes slightly irregular.

The berries are medium to large, broad-conic, uniform scarlet, with flesh usually of the same color but sometimes pink, quality fair, seeds prominent, yield and firmness medium

First bloom May 19th, abundant bloom May 27th. First ripe berries June 20th, last picking July 7th.

The variety is not promising with us, but is reported to be very firm and of good quality at the Michigan Station.

Atlantic.—bisexual.

This variety is much like Seedling of Downing, a tall, vigorous grower, setting runners abundantly. The leafstalks are long and slender, the leaflets are medium to large, eliptic-oval. New foliage is pale, old foliage dark green, veins deeply impressed, trusses medium long, upright, rather slender, many-branched, bloom abundant, flowers medium size, petals usually five.

Berries large, short-conic, light red to scarlet in color but disposed to be green in spots, flesh white to light scarlet, seeds light, coloring in advance of the flesh and not set in deep pits, quality good, firm.

Blooms early. In 1896 it was in full bloom on May 12th and one half of the blossoms were killed by frost. Normally first bloom May 14th, abundant bloom May 23d. First ripe berry June 8–17th, last picking July 8th

The variety is unproductive and unworthy of further trial.

Barton. –pistillate. Originated in Kentucky from seed of Longfellow.

Plants medium to large, setting young plants freely, foliage ample, leaflets broad, deeply and sharply notched, inclined to be light green in color, trusses medium long, fairly stout, sometimes decumbent, bloom fairly abundant, flowers medium to small, usually with five small, pointed sepals and five nearly round petals, stamens none, pistil light green.

Berries medium to large, broad-conic with an acute point, scarlet color but often pale at tips, seeds prominent, quality and yield good.

First bloom May 12 14th, abundant bloom May 20th. First ripe fruits June 14th, last picking July 17th.

The variety is quite subject to frost injury, but promises to be medium to good in value. At the Georgia Station it ranks good in productiveness, medium in quality and firmness and poor in vigor.

Beder Wood.—bisexual. Originated with Mr. Beder Wood, of Moline, Ill., 1887.

This is an early, vigorous variety, producing plants in abundance. The leafstalks are stout and often over six inches in length, the leaflets long-ovate and

dark green, trusses medium long, stocky, holding the blossoms as high as the foliage, bloom abundant, flowers medium size, regular, calyx rather small, with narrow, acute and often reflexed sepals. The stamens are numerous and well developed, pistils are pale in color.

Berries medium to large, uniform, nearly globular to short-oblong, frequently with a short neck, symmetrical, scarlet all over, seeds deeply set, flesh light colored, quality excellent, quite firm.

First bloom usually May 14-16th, abundant bloom May 19th. First ripe berry June 11th, full yield June 21st, last picking July 10th.

Although blooming early, it is but slightly injured by frost. We regard this as one of our most valuable varieties, especially desirable as a pollinizer for Warfield and other pistillates. It ranks well in value at the Kansas, Michigan, Montana and New York Stations, but is reported poor in quality, firmness and vigor at the Georgia Station.

Belle of LaCrosse.—bisexual. Originated with M. T. Crawford, Ohio.

This is a strong and vigorous grower, blooming freely but not setting many plants. It is well adapted to hill culture. The plants are large with broad crowns, leaflets medium to large, light to medium green, leafstalks medium to long, stout, trusses medium long, stout, upright, producing many blossoms and berries, flowers small to medium, petals usually five but often with an incomplete and undeveloped inner circle.

Berries medium size, conic, pointed, light scarlet shaded with crimson, flesh scarlet, seeds deeply set in irregular pits, quality good, acid, firm, yield abundant.

First bloom May 12–17th, abundant bloom May 24th. First ripe berry June 13–14th, first picking July 1st, good picking July 7th, last picking July 15th.

This variety is a late bloomer, but little injured by frost and is valuable with us. It is regarded valuable at the Michigan Station.

Bessie.—pistillate.

Plants medium to large, vigorous, light to dark green in color, foliage healthy, leafstalks erect, leaflets medium to large, long-ovate, trusses long, bloom scant, flowers medium size, petals five, stamens none.

Berries small to medium, conic, hull with difficulty, color deep red including flesh, firm.

First bloom the 17th, abundant bloom the 28th of May. First ripe fruit June 11th, first picking June 13th, last July 2d.

An excellent variety in growth and vigor but too unproductive with us to be of value. It is reported fairly vigorous, productive and of good quality and firmness at the Michigan Station.

Beverly.—bisexual. Originated with Benj. M. Smith, Beverly, Mass.

This is a second early sort, ripening with Warfield. It is a vigorous grower of medium habit, leaflets dark green in color, medium to large, broad, serrations deep, acute and usually overlapping, trusses long, upright, bloom abundant, flowers medium size, petals five, symmetrical, sometimes with a defective inner circle, stamens rather small, numerous and well developed, pistils pale green.

Berries medium size, globular to conic, seeds deeply set, surface rough, crimson, a little tardy in coloring at tips, quality good, acid, yield fair to good.

First bloom 12 18th, abundant bloom 24th of May. First ripe berries June 15–19th, first picking June 20th, best June 27th, last July 10th.

Variety of medium value with us and so reported from the Georgia and Michigan Stations.

Bisel.—pistillate.

Plants vigorous, medium in size, leaflets rather small, broad, dark green, trusses large, stout, bloom sufficient.

Berries small, conic with sharp apex, crimson, tip lighter, core slightly cartilaginous, yield only fair.

First bloom May 19th, abundant bloom May 24th. First ripe fruits June 19th, last picking July 2d.

So far the variety has done poorly with us. It is reported very favorably from the Montana Station but much less so from Georgia.

Boynton.—pistillate. Originated in N. Y., probably a cross between Crescent and Sharpless.

While ranking as a pistillate it is apparently capable of self fertilization. It is a vigorous variety, forms plants abundantly, leafstalks medium to long, slender, leaflets medium size, oblong, deeply and sharply toothed, medium to dark green, trusses medium to long, ascending, branches short, bloom abundant, flowers small to medium, petals usually five, round but sometimes pointed, not imbricate, stamens more developed than with most pistillate varieties but still rudimentary.

The berries are much of the Crescent type and character, medium size, short-conic, scarlet, flesh light, core somewhat cartilaginous, quality good, acid, flesh firm, yield good.

First bloom May 12-15th, full bloom May 20th. First ripe fruit June 10th, first picking June 13th, full picking June 26th, last picking July 13th.

The chief fault of this variety is that the berries become very small towards the close of the season. Although inclined to be soft, it is reported very favorably from the Kansas and the Minnesota Stations. At the latter Station it does best in hill culture.

Brandywine.—bisexual. Originated in Eastern Pennsylvania. Supposed to be a cross between Glendale and Cumberland.

The plant is of rather low habit, forming young plants abundantly. The leafstalks are short and stout, the leaflets large and broad, dark green in color, trusses medium length, stout, bloom production medium, anthers numerous, large and well formed.

Berries large, broad-conic, crimson, flesh ditto, slightly cartilaginous.

First bloom May 18 22d, abundant bloom May 29th. First ripe berry June 21st, last July 12th.

This is a variety of but medium value here. It is reported very favorably from the Georgia and the Michigan Stations, fairly well from Pennsylvania, but very poorly from Montana.

Bubach (No. 5).—pistillate. Originated with J. G. Bubach, Princeton, Ill.

The plants are vigorous, leafstalks medium to long, leaflets large, broad, coarsely and abundantly toothed, frequently with small interposed serrations, dark green, trusses not numerous, medium length, bloom scant, flowers fair size, often quite irregular.

Berries medium to large, conic, flattened at tips, colored well into the flesh but not uniformly on the surface, firm, seeds deeply set, quality fair, yield poor.

First bloom May 19th, abundant 28th. First ripe berry June 15th, last July 10th.

The variety is reported poorly from the Georgia Station, but quite favorably from the Kansas, Michigan, Montana and Pennsylvania Stations and from Sheridan and Lander in Wyoming.

Capt. Jack.—bisexual. Originated in Missouri with a Samuel Miller.

The variety is a vigorous grower, producing plants in great abundance. The leafstalks are short and stout, the leaflets are medium size, broad-oval, dark green, leathery, notches equal and similar, main axes of trusses stout and upright, branches long and spreading, bloom abundant and held above the foliage, flowers medium size, broadly expanded, petals usually five, round, flat, stamens numerous and well developed.

Berries light crimson, regular conic form, size medium, color uniform, flesh lighter, quality fair to good, a good shipper, quite productive.

First bloom May 12-17th, abundant bloom May 20th. First ripe berry June 6–10th, full picking June 20–27th, last picking July 10th.

This is a good early to mid-season variety, but the berries become too small later. It is an excellent pollenizer and is reported quite favorably from Kansas and Wyoming.

Carrie.—pistillate. A seedling of Haverland.

Plants large and vigorous, reproducing sufficiently. The leafstalks are stout, leaflets medium to large, dark green, leathery, trusses long, ascending, bloom abundant, flowers medium size, stamens large for a pistillate variety.

Berries resemble Haverland but are considerably larger, scarlet, firm, quality excellent.

First bloom May 19th, abundant bloom May 20–26th. First ripe fruits June 20–23d, last July 2d.

We consider this variety worthy of further trial. It is reported favorably from Michigan and Pennsylvania.

Cornelia.—bisexual.

This variety appears to be exactly like Glendale.

First bloom May 12th, full bloom May 25th. First ripe fruits June 17th, first picking June 22nd.

Reported favorably from Michigan and Pennsylvania.

Crawford.—bisexual. Originated with M. T. Crawford, Ohio.

The variety lacks vigor, producing but few plants. It has done too poorly to be worthy of description or further trial by us.

Crescent.—pistillate.

Plants of medium habit, very healthy and hardy, setting runners abundantly. The leafstalks are slender, leaflets long, frequently with two series of notches of very different size, color dark green, trusses medium length, bloom abundant, flowers small to medium, petals five, stamens rudimentary.

Berries medium size, conic with prolonged point, colored well, quality fair, acid, core somewhat cartilaginous, firmness and productiveness good.

First bloom May 12–16th, abundant bloom May 22d. First ripe berry June 7-15th, first picking June 15–20th, full picking June 27th, last July 10th.

The small size of the fruit, especially late in the season, is its chief fault. It is reported very vigorous and productive and of good quality and firmness from Georgia, Kansas, Michigan, Montana and Wyoming.

Cumberland. -bisexual.

Plants large, vigorous, setting young plants in sufficient numbers. The leafstalks are short and stout, the leaflets broad, roundish, bluntly toothed, medium dark green, trusses short to medium, stout, rays slender, bloom sufficient, flowers medium size, petals round, stamens well formed.

Berries large, short-conic to nearly globular, pale red, flesh light, hulls easily detached, appearance neat and smooth, quality excellent, rather soft, yield good.

First bloom May 15th, abundant bloom May 26th. First ripe fruits June 6–12th, first picking June 8–14th, full picking June 20–27th, last July 17th.

The variety is but slightly subject to frost injury. It is reported fair in Georgia, good in Kansas and very good at Sheridan, Wyoming.

Edgar Queen.—pistillate.

The plants are large and vigorous with abundant foliage, leafstalks are long and stout, leaflets medium to large, broad ovate, medium shade green, teeth deep and sharp, trusses long, upright, stout, bloom very abundant, flowers medium size, petals six or more, frequenty the inner petals forming rudimentary stamens.

Berries medium to large, globular, scarlet but not uniformly colored, quality fair to poor.

First bloom May 22d, abundant bloom May 29th. First ripe fruits June 18th, full picking June 27th, last July 12th.

The variety is a late bloomer but has the fault of light color, the fruit being green in spots. Many berries failed to develop. It is reported very favorably from Georgia and Michigan but only fairly so from Montana.

Edwards' Favorite.—bisexual. Probably a seedling of Jucunda.

Plants small to medium size, vigorous, producing runners freely. The leafstalks are short and very strong, leaflets ample, light glossy green, medium size, short, broad-ovate, serrations broad and rounded, trusses medium length and thickness, upright, bloom abundant, flowers medium to large, petals usually five but often more, frequently curled, pollen sufficient, calyx adherent.

Berries especially beautiful, large, uniform size, short-conic, smooth, bright scarlet, seeds light color, flesh firm.

First bloom May 10–16th, full bloom May 21st. First ripe berry June 15th, full picking June 20–27th, last July 17th.

The variety is an early bloomer. It is reported very favorably, except in vigor, from the Michigan Station.

Enhance.—bisexual.

Plants medium to large, vigorous, medium to light green, leafstalks long slender, erect, leaflets medium size, oval, teeth long and sharp, trusses short to medium, bloom abundant, flowers large, petals usually more than five, irregularly arranged, stamens well formed.

Berries medium size, crimson, tips slow in coloring, badly ribbed and irregular, sour, firm.

First bloom May 10-15th, full bloom May 12-23d. First ripe berries June 10-15th, first picking June 15-20th, full picking June 27th, last July 17th.

The variety is better for hill culture than for growing in matted rows. It is of low value with us, although it is a fairly good fertilizer for Bubach. It is reported very favorably from Georgia and Michigan and fairly so from Montana.

Eureka.—pistillate. Originated with Geo. Townsend, Soneham, Ohio, 1881.

Plants small to medium, producing sufficient young plants, leafstalks long and fairly strong, leaflets medium size, broad to long-ovate, deeply, sharply and irregularly notched and medium to dark green, trusses irregular in length, usually long and but little branched, mostly prostrate when loaded with fruit, bloom abundant, flowers small to medium, petals five to six, usually more, stamens undeveloped.

Berries large, scarlet to crimson, pink flesh, conic, frequently irregular in form and slow in coloring at tips, quality good, acid, firm, yield fair to good.

First bloom May 18-20th, full bloom May 26th. First ripe berry June 13-17th, full crop June 27th to July 6th, last picking July 17th.

The variety is late in blooming and ripening. It is of medium value with us. In Southern California it ranks low in bearing and in growth of vine.

Gandy.—bisexual.

Plants large and vigorous, do not run freely, best adapted to hill culture. Leafstalks very stout, leaflets large, long-ovate, coarsely toothed, medium to dark green, trusses long and stout, bloom abundant, flowers large, petals often more than five and frequently folded and irregular in appearance, stamens well developed, calyx large and reflexed.

Berries large, irregular, short-conic, frequently with a short neck, color bright scarlet, sometimes slow in coloring at tips, flesh light colored, seeds prominent, quality fair to good, firm.

First bloom May 17th, abundant bloom May 26th. First ripe berry June 18-21st, full picking June 26th to July 7th, last July 15th.

The variety is late in blooming and ripening and is of but moderate value. It is reported most unfavorably from Georgia, moderately favorably from Kansas, and very favorably from Michigan, Montana, New York, Pennsylvania and Sheridan, Wyoming.

Glendale.—bisexual.

Variety of tall habit, light green color, vigorous, produces sufficient young plants, leafstalks long, carrying the leaves frequently eight to twelve inches high, leaflets eliptical or oblong, finely serrate, trusses very long, bloom abundant, flowers medium to large, petals usually five but occasionally numerous, stamens fairly numerous and well developed, the first flower of each truss usually more or less compound.

First bloom May 19th, abundant bloom May 27th. First ripe fruit June 20-25th, full picking June 20th to July 6th, last July 17th.

The variety is like Seedling of Downing. It is of but little value here. The Kansas Station reports it very unproductive.

Greenville.—pistillate.

Plants large, dark green, vigorous, forming full matted row, leafstalks tall, leaflets large, broad, dark green, often streaked with light, sometimes curled slightly, coarsely notched, trusses medium long, stout, bloom sufficient, flowers small to medium, petals five to six, stamens none.

Berries medium to large, broad-conic, symmetrical, crimson, flesh colored, quality, firmness and yield good.

First bloom May 16th, abundant bloom May 22d. First ripe berry June 11-13th, first picking June 13-15th, full picking June 20-27th, last July 17th.

This is one of our best medium to late varieties. It is reported unfavorably from Georgia, Montana and Southern California Stations, but quite favorably from New York and Michigan.

Gold.—pistillate. Originated with P. M. Angar & Sons, Conn., 1880.

Plants medium size, pale yellowish color, lacking in vigor. Leafstalks medium length, somewhat drooping, leaflets medium size, broad-oval, trusses short, stout, bloom sufficient, flowers small, petals usually five with occasionally a partial inner circle.

Berries medium to large, short-conic, scarlet, flesh ditto, quality fair to good yield poor.

First bloom May 12th, full bloom May 22d. First ripe berry June 16th, first picking June 17th.

The variety is not a success under our conditions. It is reported quite unfavorably from Georgia and Sheridan, Wyoming.

Gov. Hoard.—bisexual. Originated in Wisconsin, a seedling of Sharpless.

The plants are large and quite reproductive. The leafstalks are long and stout, leaflets large, broad-ovate, medium green, trusses medium length, stout, bloom abundant, flowers large, petals usually five, stamens well formed.

Berries medium size, short-conic with neck, red all over, flesh colored well in, only fair in quality, firmness and yield.

First bloom May 12th, first picking June 17th.

Subject to frost injury, of no value on our grounds. Reported quite favorably from the Michigan Station.

Gypsy.—pistillate.

Plants of low habit, forming a thickly matted row. Leafstalks short and stout, leaflets broad, coarsely toothed, dark green in color, trusses short to medium, bloom sufficient, flowers small to medium, petals usually five, stamens none.

Berries medium size, short, round-conic, very symmetrical, uniform deep crimson color, flesh ditto, quality excellent, firm, yield medium.

First bloom May 16-18th, abundant May 21st, full bloom May 25th. First ripe berry June 5-14th, first picking June 11-15th, full picking June 20-27th, last July 12th.

We consider this an excellent variety and worthy of further trial. It is reported very favorably from Michigan, but at the Kansas Station is said to be a complete failure.

Haverland.—pistillate.

Plants of medium size, healthy and fairly vigorous although somewhat subject to leaf-curl. Forms a poor stand in matted row. Leafstalks are medium long, leaflets medium to large, rather broad, sharp toothed, medium shade green, trusses short to medium, more or less prostrate with twelve to sixteen blooms per truss, flowers small, parts arranged in plan of five, stamens none.

Berries very long with a neck, light scarlet, flesh ditto, quality very good, yield good.

The trusses are not strong enough to support the fruit. The calyx is somewhat reflexed.

First bloom May 8th, abundant bloom May 18th, full bloom May 21st. First ripe berries June 5th, first picking 8-10th, full picking 27th, last picking July 10th.

Although the blossoms and leaves are somewhat subject to frost injury we regard this as one of our best early varieties. It is reported unfavorably from Georgia though quite productive, fairly well from Kansas and Montana, and quite favorably from Michigan, New York and Sheridan, Wyoming.

Hersey.—bisexual. Originated with Samuel Hersey, Hingham, Mass.

Plants are of large and vigorous habit, reproducing abundantly. The leaf-

stalks are short and stout, the leaflets large, elliptical, teeth short and sharp, trusses long, bloom sufficient, anthers numerous but often poorly developed.

Berries large, long-conic with neck, color good, yield poor.

First bloom May 17-19th, abundant bloom May 28th. First ripe berry June 20th, best yield June 28th, last July 12th.

The variety is unworthy of further trial here. It is reported unproductive at the New York Station.

Ironclad.—bisexual.

Plants are of low habit, vigorous, reproducing fairly well. The leafstalks are short and stout, leaflets oval or broad-ovate, glossy dark green color, trusses medium length, stout, bloom abundant, flowers small to medium, petals five, stamens numerous and well developed.

Berries small to medium, conic with tips, color dark red, flesh ditto, quality good, firm, yield low.

First bloom May 13th, abundant bloom May 19th. First ripe berry June 13th, first picking 17th, full picking June 20-27th, last July 12th.

The variety will be discarded as unworthy.

Ivanhoe.—bisexual. Originated in Southern Ohio with Geo. W. Trowbridge, of Hamilton county.

Plants thrifty, foliage ample, leathery, dark green, blossoms medium size.

Berries large, conic, symmetrical, colored well, quality excellent but with a slight core.

First bloom May 21st, abundant bloom May 25th. First ripe berry June 20th.

This is a promising variety here. It is reported favorably from the Montana Station.

Jay Gould.—pistillate. Originated in Eastern Ohio, 1887.

The plants are of medium size and color, trusses medium long, bloom scant, flowers medium to large, showy, petals five to eight in a single circle.

Berries small, round-conic, crimson, flesh lighter, much like Gypsy in form, color and flavor, but smaller.

First bloom May 16th, abundant bloom May 24th. First ripe berry June 14th, last picking July 12th.

Variety undesirable here. Reported very favorably from the Michigan Station but unfavorably from the Montana Station.

Jessie.—bisexual—pistillate. Originated with Jas. W. Loudon, Janesville, Wis.

Plants very large and vigorous, producing young plants freely. Leafstalks long, leaflets very long, teeth large and irregular, medium green, trusses long and stout, bloom abundant. We have two stains of the variety. The flowers are large in the perfect-blossomed strain and small in the pistillate. Both strains are very productive of large berries, the earliest of which are often flattened and slow in coloring at tips.

Berries light scarlet, flesh lighter, quality good, calyx large, seeds prominent, quite firm.

First bloom 12-14th, abundant bloom May 23–24th. First ripe berry June 10–12th, last picking July 17th.

The development of the pistillate strain is slightly in advance of the staminate. The chief fault of the variety is the uneven ripening of the first fruits. At the Southern California Station it ranks low in production and growth of vine, at the Kansas Station very low in production, at the Georgia Station it is regarded as a good variety for amateur culture only, and in Wyoming it is not very successful, but is reported very favorably from the Michigan Station.

Jucunda.—bisexual.

Plants large, medium green, leaflets large and long, trusses long, bloom abundant, flowers large, petals usually five but frequently numerous in a single circle, stamens well developed.

Berries large, conic, frequently ribbed and irregular, quality fair, acid, yield medium.

First bloom May 12, full bloom May 22d. First ripe berry June 12th, first picking June 13th, last July 15th.

The variety was not a success here.

Jucunda Improved.—bisexual. Originated with A. B. Gerbert, of Eastern Pennsylvania. Probably a seedling of Jucunda.

The variety forms a thick mat of rather small plants, leaflets broad, medium green, bloom production fair, flowers large, petals usually six to seven but sometimes more, stamens well developed.

Berries a little broader than Jucunda, very large, crimson, surface smooth, short-conic, symmetrical, flesh pink, quality good, firm, yield low.

First bloom May 19th, abundant bloom May 29th. First ripe berry June 18–20th, full picking June 27th, last picking July 17th.

The variety rusts badly and is of little value here. It is reported very unfavorably from Georgia but quite favorably from Wyoming.

Jumbo.—bisexual.

A variety of the Sharpless type. Plants medium to large, medium vigor, fairly productive, leafstalks stout, medium to long, leaflets, large and broad-oval, deeply and sharply toothed, medium green in color, trusses medium long and medium stout with spreading, ascending branches, bloom production medium, flowers medium to large, petals usually six to ten, all somewhat curled, stamens imbricate and well developed.

Berries large to very large, oblong or somewhat rectangular, disposed to be irregular in form, color bright scarlet but slow in coloring at the tips, flesh nearly the same color, core somewhat stringy, quality fair, firmness and production medium.

First bloom May 9–12th, full bloom May 20th. First ripe berry June 15–18th, first picking June 19–20th, full picking June 26th, last July 8th.

This is a variety of strictly medium value here.

Lady Rusk.—pistillate.

The plants are large, running freely and making a full matted row. The leafstalks are long and stout, leaflets medium to large, long-ovate, rather unevenly toothed, medium to dark green, trusses medium to long, moderately stout, bloom production moderate, flowers small to medium, petals normally five, usually with undeveloped inner circle of two or three, stamens quite well developed for a pistillate variety.

Berries medium size, short, surface uneven and often more or less ribbed, dark crimson, tips slow in ripening, flesh yellowish pink, core soft or cartilaginous, quality and yield fair.

First bloom May 14–18th, abundant bloom May 21–23d. First ripe berry June 11–17th, first picking June 17-20th, full picking June 27th, last picking July 10th.

The plants and fruit much resemble the Crescent, although the fruit is more irregular in shape. It is a variety of medium value here. It has done fairly well in Kansas and Wyoming.

Lady Thompson.—bisexual.

Plants of medium habit, setting runners freely, large, vigorous, dark green, bloom sufficient, flowers large, stamens well formed.

Berries fair size, symmetrical, conic, often gemmate or twined, quality fair, yield good.

First bloom May 22d, abundant bloom May 25th. First ripe berry June 19th, last picking July 2d.

The variety is only moderately promising. It has done fairly well at the Georgia Station, but is pronounced a failure in New York, Ohio and Southern California.

Leader.—bisexual. Originated in Reading, Mass.

Plants of medium habit and vigor, producing young plants in sufficient number. Leafstalks short, leaflets medium to large, medium green, nearly round, small serrations frequently occurring between the larger ones, trusses medium long, stout, bloom production medium, flowers large and showy, calyx

large, sepals and petals usually exceeding the normal number, stamens numerous and well developed, pistils ditto.

Berries large, broad-conic and symmetrical but quite small after the first few pickings, deep scarlet, flesh ditto, seeds prominent, crimson, firm, quality good, acid, yield good.

First bloom May 16, abundant bloom May 21st. First ripe berry June 11-16th, first picking June 15-20th, full picking June 27th, last July 10.

The berries much resemble Warfield in shape and color. The plants have not been thoroughly healthy with us and were somewhat injured by frost in 1896. Reported inferior in production and flavor in Southern California, but very favorably except in vigor at the Michigan Station.

Lida.—pistillate. Originated with Wm. Parry, N. J., from seed of Chester.

Plants large and vigorous, reproducing freely, leafstalks medium to long, stout, leaflets medium size, broad-ovate, dark green, trusses medium to long, bloom fairly abundant, flowers medium size, petals five, many stamens fairly developed.

Berries large, short-conic or globular with a smooth surface, uniform light scarlet, flesh paler, quality good to excellent, a little soft, yield good.

First bloom May 10-12th, full bloom May 21-28th. First ripe berry June 12th, first picking June 13th.

It is reported low in vigor and production from Kansas and but slightly better from the Michigan Station.

Loudon.—bisexual.

Plants large but rather low in habit, a good plant producer, leafstalks medium long, stout, sharply and unevenly toothed, light green, trusses medium to long, stout, bloom sufficient, flowers large, petals usually five but sometimes six or more, stamens well formed.

Berries large, broad-conic, nearly globular, crimson but sometimes not uniformly so, flesh pale, quality fair to good, firm, calyx large and conspicuous.

First bloom May 10th or earlier, abundant bloom May 12-19th. First ripe fruits June 13-17th, full picking June 20-26th, last July 8th.

Variety of medium value. Reported very unfavorably from Georgia.

Louisa.—bisexual. Originated with Nicholas Hallock, of New York. Introduced by W. A. Burpee, 1888.

Plants medium to large, reproducing but moderately. Leafstalks long, medium strong, leaflets large, coarsely and often unevenly toothed, new leaves thin and light green but darker with age, flowers medium size, petals usually five, many blossoms pistillate.

Berries very large, oblong, with neck, light scarlet, flesh nearly white, seeds deeply set, flavor excellent, a little soft.

First bloom May 19th, abundant bloom May 26th. First ripe berry June 10-15th, first picking June 15th, full picking June 20th to July 7th, last July 15th.

A very good variety. Reported low in vigor and productiveness at the Kansas Station.

Lovett.—bisexual. Originated in Kentucky in 1885. Believed to be a chance seedling of Crescent x Wilson.

Plants of medium habit, healthy but somewhat subject to leaf curl, quite reproductive, leafstalks medium long, stout, leaflets medium size, thin, broad-ovate, sharply and irregularly toothed, medium to dark green, trusses short, stout, bloom abundant, flowers medium to large, petals usually five but frequently six to eight, stamens medium and well developed, calyx large.

Berries medium size, conic to long-conic, crimson, quality good, acid, firm, yield medium.

First bloom May 15-17th, full bloom May 22d. First ripe berry June 10-14th, full picking June 20-27th, last pick July 7th.

A variety of medium value here. Reported very unfavorably from Georgia, but better from Michigan, Montana and Sheridan, Wyoming.

Louella.—bisexual.

Plants large and vigorous, reproducing abundantly. Leafstalks medium long, erect, stout, leaflets large, long-ovate, medium green, trusses long and strong, bloom abundant, carried high, flowers large, petals five to six, stamens well developed, pollen very abundant.

Berries large, irregular-conic with neck, dark red, tips frequently green, flesh highly colored, quality good, acid, yield medium.

First bloom May 17th, full bloom May 21–27th. First ripe berry June 11th–23d, first picking June 15th, full picking June 27th, last July 15th.

Manchester.—bisexual.

Plants of medium habit, dark green, leathery, very like if not identical with Cumberland. Leafstalks short and stout, leaflets large, broad to round, serrations short, blunt and irregular, trusses medium long, bloom fairly abundant, flowers medium to large, petals usually five, stamens well developed.

Berries large, broad-conic, symmetrical, surface smooth and even, light scarlet, flesh light, seeds prominent, quality very good, not firm, yield fairly good.

First bloom May 10th, full bloom May 25th. First ripe fruit June 11–14th, first picking June 20–27th, last picking July 15th.

The variety is reported very productive at the Kansas Station,but is reported quite unfavorably from Georgia and from Sheridan, Wyoming.

Margaret.—bisexual. Originated with Jno. F. Beaver, Dayton, O., about 1891, from seed of Crawford.

The variety is a vigorous grower of medium habit, reproducing fairly well. Leafstalks medium long, stout, leaflets broad, coarsely toothed, leathery, trusses medium long, stout, bloom abundant, flowers large, petals five to nine, a good pollenizer.

Berries large, broad-conic, light crimson on exposed surface, scarlet on shaded portions, flesh pink to white, quality good, firm, yield fair.

First bloom May 13th, abundant bloom May 22d. First ripe fruit June 13th, first picking June 20th, full picking June 27th, last July 12th.

A good variety, deserving of trial. It is reported to be a promising pistillate variety at the Pennsylvania Station.

Marshall.—bisexual. Originated in Mass., introduced to the public in 1893.

Variety medium to large, vigorous, fairly reproductive. Leafstalks medium long, stout, leaflets large, broad, irregularly toothed, medium to light green, spotted to some extent, trusses medium to long, stout, bloom scant, flowers large, petals five to seven, in one whorl, occasionally some in an inner circle.

Berries large, broad-conic, crimson, tips often greenish, quality good.

First bloom May 15th, full bloom May 22nd. First ripe berry June 13th, first picking June 30th, last July 12th.

This is a promising variety, but it probably requires extra culture. It is reported very favorably from the Georgia and Michigan Stations.

Michels Early.—bisexual.

The variety is a very vigorous grower, of medium habit, setting plants and bloom profusely. It is an excellent pollenizer.

Mrs. Cleveland.—pistillate.

Plants large and vigorous, reproducing abundantly, leafstalks stout, leaflets ample, broad, coarsely toothed, light green, trusses medium long, bloom sufficient, flowers medium size, petals usually five, stamens none.

Berries large, round-conic, surface even, light scarlet, flesh light, quality excellent, slight core, firmness medium, yield good.

First bloom May 13th, abundant May 23d. First ripe berry June 13–15th, first picking June 16th, full picking June 26th, last July 8th.

An excellent kitchen variety. It is reported fair at the Kansas and good at the Michigan Station.

Monarch.—bisexual.

The plants are large and vigorous, leafstalks medium to long, leaflets small to medium, ovate, deeply notched, light green, trusses medium to long, stout,

bloom abundant, flowers medium to large, petals five to eight, imbricate, inner ones frequently much like the stamens, stamens medium size, numerous.

Berries large, conic, pale scarlet, inner flesh white, soft, quality good, yield good.

First bloom early, full bloom 1896 May 12th, abundant bloom 1897 May 27th. First ripe berry June 8–16th, first picking June 11th, last July 17th.

While inclined to bloom early, the variety is quite late in bearing, producing its full crop the latter part of June. The berries do not ripen evenly. Reported poorly from Georgia.

Ontario.—bisexual. Introduced from Canada by R. Johnston, of New York, 1885.

The variety is not vigorous nor productive of plants. Leafstalks medium long, stout, leaflets medium to large, light green, few in number, texture thin, trusses short, stout, drooping, branches long, bloom scant, flowers large, petals usually numerous and much folded, stamens well formed, calyx large.

Berries medium to large, oblong-conic or broader, scarlet, flesh colored, quality good, yield medium.

First bloom May 11th, full bloom May 22d. First ripe berry June 12th, last picking July 8th.

The variety has not done well. The fruit and foliage are both subject to frost injury. Reported fairly well from Georgia, excellent from Michigan, but very unproductive from Kansas.

Parker Earle.—bisexual. Originated 1886 with J. Nimon from seed of Crescent x T. V. Munson's No. 3.

Plants of medium size and vigor, reproducing abundantly. Foliage abundant, leafstalks long, erect, leaflets frequently unevenly notched, medium green, trusses medium long, stout, many-branched, sometimes as many as twenty per truss, bloom abundant, flowers medium size, petals usually five well formed, stamens numerous and well developed.

Berries large, long-conic, neck long, tips truncate, seeds depressed, color uniform scarlet, flesh lighter, quality good, firm, yield excellent, calyx reflexed.

First bloom May 17th, full bloom May 22–24th. First ripe berry June 15–19th, first picking June 20th, full picking June 27th, last July 12th.

This is our very best commercial variety. It is reported favorably from Georgia and very favorably from Michigan, rather unfavorably from Montana and Wyoming and poorly from Southern California.

Pearl.—bisexual. Originated in New Jersey.

Plants of Crescent type but smaller, leafstalks medium long, leaflets small, long-ovate, medium green, but slightly injured by frost, trusses short, bloom abundant, flowers medium size, petals five, stamens well developed.

Berries large, conic, symmetrical crimson, flesh ditto, quality good, soft, yield good.

First bloom May 12th, full bloom May 22d. First ripe berry June 10th, first picking June 15th, last July 15th.

Although lying on the ground, these are among our handsomest and best berries. Reported to be lacking in vigor and yield in Georgia and Kansas.

Phillips.—bisexual. A seedling of Sharpless.

Vigorous until attacked by mildew and spot. Leafstalks medium to long, slender, foliage ample, medium to dark green, leaflets medium size, oval, trusses shorter than leafstalks, bloom scant, flowers very large, petals usually six to eight, pollen abundant for a number of flowers.

Berries large, conic, truncate, badly ribbed, unevenly crimson, quality poor.

First bloom May 19th, full bloom May 24th. First ripe berry June 20th, last June 26th.

Not a promising sort. Reported favorably from the Michigan Station and from Georgia, when grown with Parker Earle.

Princess.—pistillate. Originated in Minnesota.

A low, vigorous grower resembling Pearl, although somewhat earlier and the fruit more nearly globular. Plants small to medium, leafstalks short, leaflets

medium size, broad, medium to dark green, truss axes short to medium, bloom production fair, flowers small to medium, petals not imbricate.

Berries medium size, short-conic to globular, deep crimson, flesh light scarlet, seeds deeply set, quality and yield good.

First bloom May 10-14th, full bloom May 19-22d. First ripe berry June 6-11th, last picking July 8th.

A good early to medium variety. Reported from Georgia as a poor grower but a very heavy mid-season cropper, the best on the Station grounds. It is reported very favorably from Michigan but poorly from Montana.

Princeton Chief.—pistillate.

Variety of tall habit, vigorous, reproducing abundantly. Leaflets large, long, somewhat tapering toward apex, light green, trusses exceedingly long, somewhat overtopping the leaves, bloom very abundant, flowers large, petals five to nine, stamens considerably developed.

Berries large, dark crimson, form irregular, yield good.

First bloom May 19th, abundant May 24th. First ripe berry June 21st, last July 17th.

This is a very late, promising variety. Reported unfavorably from Montana, from Georgia as lacking in form and productiveness, but very favorably from the Michigan Station.

Puritan.—pistillate.

Plants after the Crescent type but taller and the leaflets more sharply toothed. It is a very healthy and vigorous variety, forming plants abundantly, leafstalks long and stout, leaflets medium to large, dark green, serrations small, trusses medium to long, bloom sufficient, flowers medium size, petals usually five, stamens none.

Berries medium size, conic, irregular, surface uneven, crimson, very acid, yield good.

First bloom May 16th, abundant bloom May 28th. First ripe berry June 16th. full picking June 26th, last July 8th.

A late variety, poor to medium in value.

Rio.—bisexual.

A variety of Crescent type. Plants low in habit, vigorous, reproducing freely, leafstalks short and slender, leaflets small, light to medium green, trusses short and upright, bloom sufficient, flowers medium size, petals usually five, stamens well formed.

Berries medium size, broad-conic with somewhat prolonged point, bright scarlet, flesh ditto, quality good, acid, core cartilaginous, yield fair.

First bloom May 16th, abundant bloom May 22d. First ripe berry June 13th, last picking July 2d.

The variety is not desirable under our conditions. Reported unproductive at the Georgia Station, but favorably from Michigan.

Seedling of Downing.—bisexual.

A very vigorous variety, setting runners and young plants abundantly. Plants large, leafstalks long, stout, leaflets large, long and narrow, uniformly notched, light green, truss axes long and upright, bloom abundant, flowers small, calyx especially small. bowl-shaped, stamens well formed but not numerous.

Berries medium size, long-conic, scarlet, flesh ditto, seeds deeply set, giving the surface a rasp-like appearance, the seeds on the exposed surface becoming red while the flesh is still white, quality good, not a good shipper, yield fair.

First bloom May 12th, abundant bloom May 20th. First ripe berry June 14–17th, full picking June 20–26th, last picking July 12th.

Unworthy of trial under our conditions.

Shuster's Gem.—pistillate. A cross of Crescent x Sharpless.

Variety large, thrifty, reproductive, leafstalks long, slender, leaflets large, oval, light green, trusses medium to long, upright, bloom fairly abundant, flowers medium size, petals none.

Berries medium size, conic, symmetrical, clear scarlet, flesh lighter, quality good, sweet, lacks firmness, yield good.

First bloom May 12th, full bloom May 20th. First ripe berry June 10th, first picking June 15th, full picking June 20-27th, last July 10th.

A promising variety, worthy of trial. Reported favorably from Georgia, Kansas, Pennsylvania and Wyoming, but unfavorably from Montana and Southern California.

Splendid.—bisexual.

A large and vigorous variety, producing a full matted row. Plants large, leafstalks medium to long, leaflets large, oval, pointed, dark green, trusses medium to long, bloom abundant, flowers medium size, petals five to six.

Berries large, short-conic, blunt, crimson, flesh pale pink, white toward centre, tardy in coloring at tip, quality good, core sometimes cartilaginous, yield good.

First bloom May 17th, abundant bloom May 23d. First ripe berry June 17th' first picking June 20th, full picking June 27th, last picking July 12th.

A promising variety. Reported favorably from Michigan and Montana.

Stayman's No. 1.—bisexual. Originated in Southern Ohio. A seedling of Warfield.

Plants of medium size and vigor, reproducing fairly well. Leafstalks short to medium, leaflets medium size and shape, deeply notched, dark green, truss axes long, usually declined, bloom abundant, flowers small with parts arranged in order of five, petals smooth, stamens none.

Berries medium size, sometimes with a short neck, calyx reflexed, fruit conic, frequently double or even triple, the individuals being united to the tips, scarlet, flesh pink, core frequently cartilaginous, quality fair to good, acid, yield fair.

First bloom May 13th, abundant bloom May 22d. First ripe berry June 12th, first picking June 15th, full picking June 20-26th, last picking July 15th.

A variety of very moderate value. Reported favorably from Montana and Sheridan, Wyoming, but from Georgia as being very unproductive.

Summit.—pistillate. Originated with M. Crawford, Ohio, as Crawford's No. 6.

Plants large, vigorous, reproducing abundantly, leafstalks medium long, stout, leaflets medium large, round or broad-ovate, medium shade green, bloom sufficient but many barren plants, stamens often well developed.

Berries large, uniform, short-conic, quality and yield good.

First bloom May 10-12th. First ripe berry June 5th, first picking June 13th.

A desirable berry for home use. From Kansas reported to be extremely unproductive.

Tennessee Prolific.—bisexual. Seedling of Crescent x Sharpless.

Plants of medium habit, vigorous, reproducing abundantly. Leafstalks slender, leaflets medium long, unequally serrated, trusses medium long, mostly declined, bloom abundant, flowers large, petals five to six, anthers usually well formed, but the flowers sometimes partially pistillate.

Berries small to medium, irregular, color crimson to scarlet, flesh colored, core sometimes cartilaginous.

First bloom May 17th, abundant bloom May 22d. First ripe fruits June 5th, last picking July 12th.

The value of the variety is rather uncertain. Reported rather favorably from Michigan, but as being of little value at the Montana Station.

Thompson.—bisexual.

Plants of medium size, vigorous, reproductive, leafstalks long and slender, leaflets small to medium, long, teeth sharp, medium to dark green, trusses short and stout, branches long, bloom abundant, flowers medium size, petals often over five, stamens well formed.

Berries large, uniform, conic, pointed, occasionally with neck, bright scarlet, seeds light colored and prominent, quality excellent, mild acid, firm, yield excellent.

First bloom May 9th, full bloom May 20th. First ripe berry June 5th, first picking June 15-20th, last picking July 8th.

This is our best early variety. With Haverland in seasen.

Timbrell.—pistillate. Originated with H. S. Timbrell, of New York.

The variety is large, coarse and vigorous, but it does not set young plants freely. Leafstalks long and strong, leaflets broad-ovate, foliage strong, medium green, trusses short and stout, bloom abundant on individual plants, flowers medium size, petals five, stamens usually none but often well formed.

Berries medium to large, short-conic to globular, deep crimson with paler spots, quality good to excellent, firm.

First bloom May 17th, abundant bloom May 24th. First ripe berry June 16th, first picking June 18th, full picking June 27th, last July 17th.

The variety has not succeeded well. It is reported fairly well from Michigan, but as being very unproductive in Montana and Georgia.

Tippecanoe.—bisexual. Originated from seed brought from France.

A variety of medium habit, producing plants abundantly, leafstalks medium long, stout, leaflets medium to large, broad-ovate with rounded teeth, color dark green, trusses medium long, bloom sufficient, flowers large, petals usually five to eight in a single series, stamens usually well formed but sometimes undeveloped.

Berries large, regular globular form, scarlet, sometimes a little slow in coloring at tips, flesh yellowish pink, calyx large, quality and yield good.

First bloom May 15th, abundant bloom May 24th. First ripe berry June 12-16th, first picking June 15-19th, full picking June 26th, last July 15th.

A mid-season variety. It is one of our best large berries.

Van Deman.—bisexual. Originated with a Mr. Bauer.

Plants medium size, dark, glossy green, sets young plants abundantly, leafstalks medium long, leaflets medium size, long-ovate, trusses short, stout, much branched, bloom abundant, flowers medium size, petals five, stamens numerous and well developed.

Berries medium size, conic, uniform deep red, flesh ditto, seeds prominent, quality good, yield poor.

First bloom May 12th. First ripe berry June 11th, first picking June 15th.

The variety is somewhat subject to frost injury. It is reported rather unproductive from Kansas, Michigan and Montana, but of excellent quality and firmness.

Warfield.—pistillate. Originated with B. C. Warfield in Southern Illinois, 1883. Probably a seedling of Crescent.

Plants medium size, vigorous and healthy, very reproductive, leafstalks long, slender, leaflets medium-oval but sometimes narrower, sharply toothed, medium to dark green, trusses medium long, stout, bloom abundant, flowers small, parts usually arranged in order of five, stamens rudimentary, pistils a peculiar yellow color.

Berries large, uniform, symmetrical, conic, with a sharp tip and sometimes a short neck, deep crimson, flesh ditto, quality good, acid, firm.

First bloom May 13th, abundant bloom May 19th. First ripe berry June 5-12th, first picking June 11th, full picking June 26th, last picking July 18th.

This is our best pistillate variety. It ranks next to Parker Earle as a commercial berry. Beder Wood is probably its best pollenizer.

The variety is not valuable at the Georgia Station, but it ranks high in the reports from Kansas, Michigan, Montana and Wyoming.

Westlawn.—bisexual.

Plants of tall habit, large and healthy, setting young plants abundantly. Leaflets large and broad, coarsely toothed, light green, trusses long, slender, upright, bloom sufficient, flowers medium size, petals frequently six, stamens none.

Berries medium to large, uniform, broad-conic, tip long, irregular and slow in coloring, color deep scarlet, flesh light, seeds deeply set, calyx large, parting easily from fruit, quality only fair, acid, firm, yield fair.

First bloom May 12th, abundant bloom May 22d. First ripe fruit June 12-14th, full picking June 26th, last picking July 8th.

A fair mid-season variety. Unworthy of trial.

Wilson's Albany.—bisexual.

Plants small to medium, reproducing poorly, leafstalks medium long, stout, leaflets large, broad-ovate, medium dark green, trusses medium long, stout, bloom sufficient, flowers medium size, stamens well developed.

Berries small to medium, conic, crimson, flesh ditto, quality fair, acid, yield fair to good.

First bloom May 12th, blossoms but slightly subject to frost injury.

An undesirable variety. Reported unproductive at the Montana Station.

Woolverton.—bisexual. Originated with Jno. Little, of Canada.

Variety a robust grower but not easily established on heavy soils. Leafstalks medium to long, stout, leaflets ample, deeply toothed, flexible, long-oval, medium green, trusses long, stout, upright, flowers large, petals six to seven, many flowers with some petals imperfectly formed, stamens normal, calyx conspicuous.

Berries large, conic, sometimes flat at tip, deep crimson all over and well to centre, seeds prominent, firm, yield and quality good.

First bloom May 16th, abundant bloom May 25th. First ripe berry June 8-12th, first picking June 15th, full picking June 20-24th, last July 5th.

A good variety in many places Reported quite favorably from Michigan but as being quite unproductive from Georgia.

Yale.—bisexual. Originated as a chance seedling in New Haven, Conn.

Plant of Warfield type but more robust, large and vigorous, leafstalks long, stout, leaflets long, broad, coarsely notched, dark green, trusses long, stout, upright, much branched, bloom abundant, flowers small, petals imbricate, round, stamens usually well formed but sometimes quite rudimentary.

Berries large, conic with prolonged tip, scarlet, flesh ditto, seeds light colored, quality fair, soft, yield poor.

First bloom May 14th, abundant bloom May 22d. First ripe berry June 15th, full picking June 20-25th, last July 10th.

A mid-season variety of medium value. Reported from the Georgia Station as very unproductive.

TABLE.

ABBREVIATIONS.

Sex.	*Form.*	*Size.*	*Color.*
p, pistillate.	b, broad.	s, small.	l, light.
b, bisexual.	c, conic.	m, medium.	r, red.
	d, depressed.	l, larg..	s, scarlet.
	i, irregular.		
	r, round.		
	n, with a neck.		

VARIETY.	Sex.	Vigor (1-10).	Date first bloom.	Date first ripe fruits.	Date last picking.	Productiveness, (scale 1-10).	Size.	Form.	Color.	Quality.	Firmness.
Annie Laura	b	8	May 19	June 19	July 12	6	l	dc	bc	6	7
Aroma	b	8.5	" 19	" 20	" 7	7	m-l	bc	s	7	7
Atlantic	b	8.5	" 14	" 12	" 8	7	m-l	bc	lr-s	8.5	6.5
Barton	p	8	" 13	" 14	" 17	9	m	bc	s	8.5	9
Beder Wood	b	8	" 14	" 11	" 10	8.5	m	rdc	s	8	8.5
Belle of LaCrosse	b	8.5	" 14	" 13	" 15	9.5	m	c	s-c	8	8.5
Bessie	p	8	" 17	" 11	" 2	4	s-m	c	dr	7.5	9
Beverly	b	8	" 12	" 15	" 10	7.5	m	bdc	c	8	7
Bisel	p	8	" 19	" 19	" 2	......	s	c	c	7	......
Boynton	p-b	9	" 13	" 10	" 17	9	m	bc	s	8	8.5
Brandywine	b	8	" 20	" 21	" 12	....	l	bc	dc	......	......
Bubach No. 5	p	8	" 19	" 15	" 10	9.5	m-l	ic	s	7	8
Capt. Jack	b	9.5	" 14	" 10	" 10	8	m	c	c	8	9
Carrie	p	8	" 19	" 21	" 2	8.5	m-l	lc	s	9.5	9
Cornelia	b	8	" 12	" 17	....	......	......	......	......	......	......
Crescent	p	8	" 13	" 10	July 10	8	m	lc	lc	8	8
Cumberland	b	8	" 15	" 12	" 17	8.5	l	bdc	lr	9.5	7.5
Cyclone	b	9.5	" 13	" 13	" 10	8.5	s	lnc	s	8	8.5
Edgar Queen	p	10	" 22	" 18	" 12	8	m-l	bdc	s-l	7	......
Edward's Favorite	b	8	" 12	" 15	" 17	8.5	m-l	bc	bs	9	9
Enhance	b	7.5	" 12	" 12	" 17	8	m	bic	c	8	9
Eureka	p	7.5	" 18	" 14	" 17	8	m-l	ic	s-c	8	9.4
Gandy	b	8.5	" 17	" 19	" 15	8	l	ibcn	bs	8	9
Glendale	b	8.5	" 19	" 20	" 17	7	m-l	lc	ls	7	7
Greenville	p	9	" 16	" 13	" 17	8	m-l	c	c	8	8.5
Gold	p	7	" 12	" 16	" —	5	m-l	bc	s	7.5	8
Gov. Hoard	b	9	" 12	" 14	" —	7	m	bcn	r	7	7
Gypsy	p	8.5	" 16	" 8	" 12	8	m	bc	dc	10	9.5
Haverland	p	8	" 8	" 5	" 10	9	m	lcn	ls	8.5	8.5
Hersey	b	9.5	" 17	" 20	" 12	6	l	lcn	s	7.5	8
Ironclad	b	8.5	" 13	" 13	" 12	7	s-m	lc	dr	8	8.5

TABLE—(Continued).

VARIETY.	Sex.	Vigor (1-10).	Date first bloom.	Date first ripe fruits.	Date last picking.	Productiveness, (scale 1-10).	Size.	Form.	Color.	Quality.	Firmness.
Ivanhoe	b	9	May 21	June 20	July 12	8	l	c	c	9.5	9
Jay Gould	p	8	" 16	" 14	" 12	7.5	s	bdc	dc	9.5	8.5
Jessie	b-p	10	"12-14	"10-12	" 17	8.5	l	c-ic	ls	9	9
Jucunda	b	8	" 12	" 12	" 15	7.5	l	lc	s	7.5	8
Jucunda Improved	b	8.5	" 19	" 19	" 17	7	l	c	c	8.5	8.5
Jumbo	b	8	" 9	" 15	" 8	8	l-vl	ldic	bs	7	7
Lady Rusk	p	10	" 14	" 13	" 10	7	m	bic	dc	7	7
Lady Thompson	b	9	" 22	" 19	" 2	9.5	m	c-ic	s-c	7.5	8
Leader	b	7	" 16	" 13	" 10	8	m-l	bc	ds	8	9
Lida	p-b	9	" 11	" 12	" —	8	l	bc	ls	9	7.5
London	b	8.5	" 10	" 13	" 8	8	m-l	bdc	s-c	8	9
Louisa	b-p	8	" 19	" 12	" 15	......	vl	ldcn	ls	9.5	8
Lovett	b	8.5	" 15	" 11	" 7	8	m	c-lc	c	8.5	9
Louella	b	9.5	" 17	" 14	" 15	8	l	icn	dr	8.5	8.5
Manchester	b	8	" 10	" 12	" 15	8	l	bdc	ls	9.5	7.5
Margaret	b	8	" 13	" 13	" 12	7.5	l	bc	lc	8.5	9
Mark	b	9	" 14	" 20	" 15	8	m	bc	s-c	5	9
Marshall	b	8	" 15	" 13	" 12	8.5	l	bc	c	8	8
Mrs. Cleveland	p	9.5	" 13	" 13	" 8	8.5	l	rc	ls	9	8
Monarch	b	8.5	" 8	" 10	" 17	8.5	l	c	ls	8	7
Ontario	b	5	" 11	" 12	" 8	7	m-l	ldc	s	8.5	8
Orange Co.	p	7	" 13	" 13	" 12	7	m	brc	ls	8.5	8
Parker Earle	b	9.5	" 17	" 16	" 12	10	m	lcn	ds	8	9
Pearl	b	8	" 12	" 10	" 15	8	l	c	c	9	8
Phillips	b	8	" 19	" 20	June 26	8	m	lidc	lc-c	6	7
Princess	p	7.5	" 12	" 8	July 8	8.5	m	rc	dc	8.5	8
Princeton Chief	p	9.5	" 19	" 21	" 17	8.5	l	ic	dc	8.5	8.5
Puritan	p	10	" 16	" 16	" 8	8.5	m	ic	c	7	8
Rio	b	9	" 16	" 13	" 2	7	m	lbc	bs	8.5	7
Seedling of Downing	b	9.5	" 12	" 14	" 10	7	m	lc	bs	8	7
Shuster's Gem	p	9.5	" 12	" 10	" 10	8	m-l	c	bs	8.5	8
Splendid	b	10	" 17	" 17	" 12	8.5	l	bdc	c	8	8
Stayman's No. 1	p	8	" 13	" 12	" 15	7.5	m	icn	s	7.5	8
Summit	p	9	" 11	" 5	" —	8.5	l	bc	ls	8	7
Tennessee Prolific	b	8.5	" 17	" 15	" 12	......	s-m	ic	c-s	8	8
Thompson	b	8.5	" 9	" 5	" 8	9.5	m	c-cn	bs	9.5	9.5
Timbrell	p	8	" 17	" 16	" 17	8	m-l	bdrc	dc	9	9.5
Tippecanoe	b	8	" 15	" 14	" 15	8	vl	rdc	s	8	8
Van Deman	b	9	" 12	" 11	" —	7	m	c	dr	8	8.5
Warfield	p	9	" 13	" 8	" 15	10	m	c	c	8	9.5
Westlawn	b	8	" 12	" 12	" 8	8	m-l	bc	ds	7	8.5
Wilson's Albany	b	7.5	" 12	....	....	8	s-m	c	c	7	8
Woolverton	b	8	" 16	June 12	July 5	8	l	c-ic	dc	8	9
Yale	b	9.5	" 14	" 15	" 10	7	l	lc	s	7	7

Supplementary List of Varieties.

Since the publication of our last strawberry bulletin (No. 29, 1894), the following varieties, not found in the preceding list, have been introduced to the Station grounds. Of this number a few have failed to become established. The others will be reported upon as soon as sufficient trial has been given them :

Anna Kennedy,	Berlin,	Bismark,
Bouncer,	Brunette,	Champion of England,
Clarence,	Clark Early,	Clyde,
Cyclone,	Cobden Queen,	Darling,
Downing's Bride,	Earliest,	Eleanor,
Enormous,	Erie,	Equinox,
Gardner,	Giant,	Glen Mary,
Great Pacific,	Gros Lombard,	Halls,
Hatfield,	H. W. Beecher,	Howell,
Hunn,	Ideal,	Improved Parker Earle,
Jersey Market,	Klondyke,	Laxton,
Leo,	McKinley,	Magoon,
Manwell,	Mary,	Michigan,
Murray X Early,	Nick Ohmer,	Noble,
Ocean City,	Oriole,	Patrick,
Pet,	Plow City,	Premium,
Pride of Cumberland,	Ridgeway,	Ruby,
Seaford,	Sharpless,	Sparta,
Staples,	Sunnyside,	Tubbs,
Vories,	Wild's No. 8,	Wild's No. 35.
William Belt,	Wilson,	

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The Agricultural Experiment Station

OF THE

Agricultural College of Colorado.

APIARY EXPERIMENTS.

—BY—

CLARENCE P. GILLETTE.

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APIARY EXPERIMENTS.

FOUNDATION IN COMB BUILDING.

By CLARENCE P. GILLETTE.

Honey bees collect liquid sweets from all available sources, chiefly in the form of nectar from flowers, and when the product has been elaborated in the honey-stomach and afterwards stored in comb, we call it honey.

The material from which the comb is built is not collected as wax, but is formed within the body and secreted in the form of thin scales between the abdominal segments on the under side.

As the wax is elaborated within the body, the bee must be supplied with food out of which to form it and, according to experiments reported on another page, it requires about one pound of wax for every twenty-five pounds of honey stored in comb. The food required for the secretion of wax is, for the most part, honey; and as it requires several pounds of corn to produce one pound of beef or butter, so it doubtless requires several pounds of honey as food for worker bees to enable them to produce one pound of wax.

But the consumption of honey for wax production does not represent the total cost of the wax to the colony. The bees that secrete it are called off from the field force, so that the income of the colony is lessened. In a state of nature this wax production entails no heavy drain upon the the colony, as the comb, once built, lasts for years; but where comb honey is being produced for the market, it becomes a matter of economic importance to know to what extent and in what form wax can best be furnished bees for their use in comb building.

So far as we know at present, there is but one general way to furnish the wax for this use, and that is in some form of artificial comb foundation. But their are many types of this foundation. Is it better to have the base or midrib only—the "no wall" foundation? or is it better to have the cell walls outlined for the bees? If the latter, should we have these walls short or long? In either case, is

it better to put most of the wax in the midrib or the cell walls? When it is determined how the wax is best proportioned between the midrib and cell walls, what weight of foundation is best?

The experiments here reported were undertaken for the purpose of casting some light upon these and related problems and, it is believed, with some good results. It is not to be expected that all these questions are fully settled in this paper.

DO BEES USE WAX FROM ARTIFICIAL FOUNDATIONS TO EXTEND THE CELL WALLS AND THE COMB MIDRIB?

The common belief that wax is so used was graphically proven by the following experiment:

A few sheets of thin foundation that was made black by the addition of lamp black to the melted wax were prepared for me by Mr. C. B. Elliott, of Denver. This foundation was used in sections which were placed in supers for comb honey. In some sections starters one inch wide were used, while in others were placed full sheets. The bees accepted this black foundation as readily as any and built comb upon it. A photograph of comb built upon this foundation is shown in Plate 1. At *a* is a section containing a starter one inch wide that the bees had worked but little. At *b* are two cross sections of comb built upon such a starter. The white cross-lines show where the lower edges of the starters came, and the dark color shows to what extent the foundation was used in extending the comb. At *c* is a section of drawn comb built upon a short starter as shown at *a*. The white line marks the lower margin of the foundation, and the dark color in the comb shows to what extent the foundation was used in building down the comb. At *d* is shown comb built on a large piece of the black foundation. The cell walls are deep black at the bottom and gradually fade until the top or outer end of the wall is reached, where the dark color hardly shows. This could only come about by the bees using other wax, probably directly from their bodies, which was mixed with the wax of the foundation.

These experiments prove so conclusively that bees do use wax from foundations to extend both cell walls and midrib, that we are now ready to ask:

IS THE WAX OF THE MIDRIB OF THE FOUNDATION USED IN COMB BUILDING, AND, IF SO, WILL IT BE CUT DOWN TO THE THINNESS OF THE MIDRIB IN NATURAL COMB?

To determine these points we shall have to compare the thickness of the artificial foundation with the thickness of the comb midrib built upon the foundation, and the latter with the midrib of comb built entirely by the bees.

Table Showing the Weight, in Grains per Square Inch, of Different Kinds of Artificial Foundation, and of the Midribs of Comb Built upon Each.

	Very Heavy Foundation	Medium Brood Foundation		1898 Deep-Cell Foundation*			Thin Super Foundation		Extra Thin Foundation		† 1899 Deep-Cell Foundation		Midribs of Natural Worker Comb
Entire Foundation	Midribs of Comb on	Entire Foundation	Midribs of Comb on	Entire Foundation	Midribs of Foundation	Midribs of Comb on	Entire Foundation	Midribs of Comb on	Entire Foundation	Midribs of Comb on	Entire Foundation	Midribs of Comb on	
H. 12.	10.10	8.80	6.87	5.55	2.55	4.10	4.20	3.70	3.64	3.12	5.12	3.74	3.20
L. 10.	7.00	8.10	3.50	5.38	2.40	3.00	4.00	2.40	3.53	2.75	4.44	2.83	1.65
Ave. 11.	8.00	8.40	5.18	5.46	2.50	3.44	4.07	3.00	3.60	2.95	4 50	3.22	2.10
Heavier Than Natural Midrib.	5.90	——	3.08	——	.40	1.34	——	.90	——	.85	——	1.12	——

The accompanying table gives, in the upper line, the heaviest weights found; in the second line the lightest weights; and in the third line the average weights, computed from a good number of examples in each case. The excess in weight above that of the midrib of natural worker comb is given in the bottom line.

The differences in weight between these foundations and the midribs of comb built upon them do not represent the weight of the wax removed from the midrib of the foundation by the bees, as the foundation has short cell walls which are also thinned. These may be seen by looking at illustrations of sections of foundation in Plates 2 and 4. It will be seen by the table that none of the comb built on foundation has a midrib as light as that of the natural worker comb, though, in some cases, the midribs of comb on thin and extra thin super foundations and on the "1899" deep-cell foundation are but little heavier than those of natural comb.

It will also be noticed that, while the midrib of the "1898" deep-cell foundation itself was but little heavier than that of natural worker comb, the comb built upon this foundation had a midrib much heavier than that of the natural. The reason for this will be given directly. The table also shows that the heavier the midrib of the foundation, the heavier will be the midrib of the comb upon the foundation. This would be a general rule that might have exceptions.

* This foundation was obtained for experiment in 1898, when it was comparatively a new product, so I have called it "1898" deep-cell foundation to distinguish it from the foundation mentioned below.

† Samples of this foundation were first received in 1899, and I have designated it the "1899" deep-cell foundation to distinguish it from the preceding.

The above table shows that the very heavy foundation gave a comb midrib weighing 5.90 grains more to the square inch than the midrib of natural comb. Medium brood foundation gave a midrib 3.08 grains heavier to the square inch, or almost two and one-half times the weight of natural midrib. The lightest midribs were obtained by the use of extra thin and thin super foundations, averaging but .85 to .90 grains to the square inch more than natural midrib.

The use of the "1898" deep-cell foundation manufactured by Mr. E. B. Weed gave rather surprising results. The midrib from the foundation, before it had been worked over by the bees, averaged but .40 grains to the square inch more than the natural midrib, while the midrib of comb built on this foundation weighed 1.34 grains more. The midrib of this foundation was not uniform in thickness, in some places being thinner and in others thicker than in natural comb, as shown in Plate 4, Fig. *d*. Where the midrib was thick there was little or no thinning by the bees, but where it was very thin they reinforced the weak places by "plastering" on a quantity of wax. These thickened places are plainly shown at *n*, Fig. *c*, and at *f* of the plate just mentioned; and at *b* of Plate 1, and account for the increased weight of the comb midrib. Fig. *f*, just mentioned, is from one of the worst samples I have seen. Natural midrib is shown at *e*.

The difference in weight between the heavier artificial foundations and the midribs of the comb built upon them is too great to result from the thinning of the short cell walls alone, and can only be accounted for on the supposition that the bees do remove wax from the midribs of these foundations. The examination under a microscope of any heavy foundation that the bees have just begun to work will show the marks of their mandibles in the wax. At first the wax is left very rough, as shown in Plate 1, Fig. *g*, considerably magnified. At *h* is shown the smooth bottoms of the finished cells on the same foundation, which was medium brood in both cases.

To be convinced that heavy foundations have their midribs thinned, but not thinned to correspond with the midribs of natural comb, the reader has only to look at the figures in Plate 2. At *a* is shown a section of heavy foundation, and at *b* and *g* are shown midribs of comb built on this foundation. The lower third of *b* is a midrib of natural comb built on the foundation. At *c* and the lower end of *d* are shown sections of the medium brood foundation, while the upper portion of *d* and all of *e* show to what extent the midrib of this foundation was thinned. Notice also in this connection, that the full thinning of both foundation and cell walls is accomplished while the walls are yet quite short.

The fact that foundations are thinned was also shown by actual

measurements. A large number of *plaster casts of comb on different foundations and of the foundations themselves were made, and then cut in different directions as shown in Plates 2 and 5. This made it possible to cut the wax of the different cells so that the thickness could be measured. A large number of measurements were made and tabulated, but the variations are so great in thickness of both midribs and cell walls in all kinds of comb that I have thought it not worth while to include the table here, but will state the general results.

† The common range in thickness of the midrib in naturally built worker comb was found to be between .08 and .16 millimeters.‡ In drone comb the common range was between .12 and .20 millimeters. None of the midribs of comb built on artificial foundations averaged as thin as the natural midrib in worker comb. In some cases those from thin and extra thin super foundations, and the "1899" deep-cell foundation approximated it closely. Where the midrib of a foundation is not thicker than about .17 millimeters, the bees seem not to thin much if any, though they go over the surface with their mandibles and scrape it so that it loses its tranparency.

It was also noticed that the midrib of any comb was thicker near its attachment, at the top, sides or bottom, than at some distance from these attachments. Illustrations of this may be seen in Plates 2 and 3. Fig. *c* of the latter plate shows a cut through the comb of a pound section made from side to side.

The heavier midrib and cell walls in drone comb are necessary to give it the same strength as worker comb, because the larger the cells the fewer the number, and the smaller the amount of wax required to build them to a given thickness.

Sections of natural worker comb are shown at *b*, *c*, and *e*, and the lower halves of *a* and *g* of Plate 3. Drone comb is shown in the lower part of *i* in Plate 2, and in *f* of Plate 3.

The midrib of comb built on "1898" deep-cell foundation was very irregular in thickness, for the reasons already given, and averaged about the same as drone comb. See Plate 4, Figs. *c* and *f*. Medium brood foundation also gave wide variations in the amount of thinning.

At Plate 2, *d* and *e*, are two of the best thinned samples I have seen, though little drawn. At *f*, Plate 5, is a sample of fully drawn comb on this foundation which has the midrib thinned but little.

At *f*, Plate 2, is shown a section of super foundation obtained from Mr. Elliott, of Denver, and at *h* is a section through comb on

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* I got this idea from Mr. E. R. Root, Editor of "Gleanings in Bee Culture."

† I have not found any samples of natural comb with as heavy cell walls as those shown on page 69 of "A, B, C of Bee Culture," Figs. 1 and 2.

‡ Reduce millimeters to inches by dividing by 25.

this foundation. The midrib averages about .17 millimeters in thickness, or fully as heavy as the midrib in drone comb. The upper half of *i* in this plate is also on this foundation, and the midrib is rather heavier than the midrib of the drone comb which the bees built, shown in the lower half of the figure.

At *j* of Plate 2 is shown a section of thin, and at *l* of the extra thin super foundations. The two differ chiefly in that the former has rather heavy cell walls, while the extra thin has almost no walls. At *k* is a section showing partially drawn comb on the thin super foundation, and at *g*, Plate 5, is a sample of fully drawn comb on the extra thin foundation. It will be noticed that the midribs of the comb samples built on these foundations are in most cases nearly, if not quite, as thick as in the foundations themselves. At *a* of Plate 3 is a section through comb, the upper two-fifths of which was built upon the thin super foundation and the lower three-fifths is natural. The midrib of the foundation seems not to have been thinned at all, and contrasts plainly with the midrib of the portion that was built entirely by the bees, and also with the midribs of figures *b* and *c* of the same plate, both of which represent natural comb.

At *g* of Plate 4 is shown a section of the beautiful "1899" deep-cell foundation, as I have termed it, that is manufactured by Mr. E. B. Weed. At *h* of the same plate is shown comb slightly worked on this foundation, and at *a* of Plate 5 is shown fully drawn comb on the same. Here again it will be noticed that the midrib is scarcely if at all thinned, and is as heavy as that of drone comb.

The evidence thus obtained by measuring the thickness of the midribs of foundations and of the comb built upon them bears out the results obtained by weighing, namely, that heavy foundations have their midribs thinned some, usually much, by the bees when they build comb upon them; but these are not thinned, in any case, to the lightness of natural worker comb. If the midrib is not thicker than .17 millimeters—.068 of an inch—the bees thin it little if any; if the midrib is much thinner than the normal, the bees are likely to thicken it by the addition of wax, making it much heavier than in natural comb.

DOES THE USE OF ARTIFICIAL FOUNDATIONS RESULT IN THICKER CELL WALLS IN THE COMB?

It is evident that a slight thickening of the cell walls increases the weight of the comb more than the same thickening of the midrib. *Cheshire estimated that the area of the cell walls of worker comb one inch thick is fully ten times that of the midrib upon which they are built. If this be true (and the difference in area is

* "Bees and Bee-keeping," Vol. II., page 213.

greater when the comb is more than an inch thick), then the thickening of the cell wall by .01 of a millimeter increases the weight of comb one inch thick as much as thickening the midrib .10 of a millimeter.

The thickness of the cell walls is much less than that of the midrib. In natural worker comb I have found it varying between .045 and .07 of a millimeter, with an average of not more than .06 of a millimeter (.0024 of an inch). It has been thought by some that, though the bees may leave a heavy midrib in comb built on foundation, they will thin the cell walls down to the thickness in natural comb.

Although the cell walls of a large number of sections of comb have been measured under the camera of a compound microscope, it is difficult to give these in tabulated form, as there is so much irregularity in thickness. The heaviest part, except the extreme outer end, is close to the base of the cell, and the thinnest is beyond the middle of its length. Where comb on heavy foundations was studied, the bases of the cells were found to have distinctly thickened walls for some distance out, and this thickening was often quite irregular, as may be seen at *o* in Figures *g*, *h*, and *i* of Plate 2, and Figure *b* of Plate 4.

None of the foundations used in the experiment gave as delicately thin cell walls as are found in natural worker comb, except the thin and extra thin super foundations and, possibly, the rather shallow deep-cell foundation put out in 1899, which was placed upon the market by the A. I. Root Co., and which is being sold quite largely this year. I was not able in many cases to detect by measurements that the cell walls on these foundations exceeded the average thickness in natural comb. The difference, if any, is very slight. Figure *g* in Plate 4 shows the thickness of the cell walls of this foundation in cross section, and at *b* of Plate 5 is shown a section of the walls parallel to the midrib and quite close to it. Figure *a* of Plate 5 is a section of fully drawn comb on this foundation, and it will be seen that the cell walls have nearly, or quite, the delicacy of those in natural comb.

The "1898" deep-cell foundation with considerably longer cell walls, as shown at *d* of Plate 4, was not nearly so well worked according to my measurements. This may be due to the fact that the walls are so high that the bees cannot reach to the bottom with their mandibles to take hold of them and pinch them to the natural thinness They can only thin the lower portion of the walls by scraping them. As a rule, I have found the lower portion of the cell walls of comb on this foundation as thick as those built on the very heavy foundations, while in some cases they have been thinned very nearly to the delicacy of the walls in natural comb. A good illustration of the latter case is shown at the upper half of *a* of Plate 4, but even this sample compared with natural worker comb

shows a difference in favor of the latter which is hardly noticeable in the photographic reproduction. On the other hand, the illustrations of sections of cell walls on this foundation shown at *d*, Plate 3, and at *c* and *f*, Plate 4, show plainly the abnormal thickness of the inner third or half of the cell walls as compared with the walls in natural comb shown in *b*, *c*, and *e* of Plate 3. In fact, a close inspection will show that in many cases the walls of the comb cells seem not to be thinner than the walls in the cells of the foundation before the bees have touched them. In all cases, with this foundation, I have found the walls of the comb cells thicker than in natural worker comb. At *i*, Plate 5, is shown a portion of Figure *d*, Plate 3, somewhat magnified. Notice the thickness of the cell walls in their basal portion.

The cell walls in Figure *h* and the upper half of *i* of Plate 2, and the upper third of *g* in Plate 3, were built on the foundation shown at *f* of Plate 2. The foundation, it will be seen, is almost without walls, yet the bases, at least, of the cell walls in the comb can be seen by the unaided eye to be sensibly thicker than in the natural comb samples.

It seems, then, that keeping the wax out of the cell walls does not entirely remedy the tendency to build heavier bases to the cell walls when plenty of wax is at hand. I do not have a test, however, on strictly "no-wall" foundation, but cannot think the case would be different than in the use of this foundation with such slight walls.

The medium brood and the very heavy foundations also gave cell walls decidedly thicker than those found in natural comb. Examples of cell walls on medium brood foundation are shown at *d* of Plate 2, and at *f* of Plate 5. In the two first mentioned figures the walls are made thinner than in the long drawn cells of the last named example. All are heavier than in natural comb.

At *g* of Plate 2 and *b* of Plate 4 are shown examples of comb on the very heavy foundation. In both cases the greater thickness of the walls is very plainly seen. In the first mentioned figure the heavy walls extend, plainly, the entire length of the cells. Compare with sections of natural comb cells in Plate 3.

These studies indicate that it is a mistake to make very deep cells in artificial foundation, unless their walls can be brought down to the thinness of the naturally built cell walls—which is probably impossible—otherwise, the bees will leave them thicker than in the natural comb. The only cell walls that were brought, practically, to the thinness of the natural comb were those built on foundations with a light base and with little wax in the cell walls. The deep cells may be of advantage in other ways, but not in getting a light comb for section honey.

COMPARATIVE WEIGHTS OF NATURAL COMB AND COMB ON ARTIFICIAL FOUNDATIONS.

There is a third method of studying the effect of foundations upon the resulting comb which, to my mind, gives the most convincing evidence. By this method pieces of natural comb and comb on different kinds of foundation were cut into blocks of known area and carefully weighed. Then the cell walls were removed from the midribs and the weight of these two portions determined separately. Then the weights of the midribs and cell walls of natural comb were compared with the corresponding parts of comb built on artificial foundations, and the midribs of the latter with their corresponding foundation midribs. In this way I was able to determine whether the cell walls or the midribs of comb on artificial foundations were as light as in the natural comb.

Table Giving Weights, in Grains to the Square Inch, of Whole Comb and of the Midribs and Cell Walls of the Comb, in Each Case Separate.

Kind of Foundation.	Thickness of Comb.	Weight of Comb.	Weight of Midrib.	Weight of Cells.	Sq.ft of Comb to make 1 lb. of Wax.
Natural Worker Comb......	1.37	13.00	2.20	10.80	3.74
" " "	1.35	12.90	2.50	10.40	3.76
" " "	1.33	12.20	2.20	10.00	3.99
" " "	1.25	12.80	2.30	10.50	3.80
" " "	1.25	10.90	2.20	8.70	4.46
" " "	1.20	9.50	2.00	7.50	5 12
" " "	1.18	9.60	2.15	7.45	5.09
" " "	1 15	9.55	1.80	7 75	5.09
" " "	1.13	9.55	2.33	7.22	5.06
" " "	1.00	10.00	2.50	7.50	4 86
" " "	.90	9.00	2.00	7.00	5.40
" " "	.90	7.60	1.80	5.80	6.40
" " "	.80	7.00	1.80	5.20	6.94
" " "	.75	6.60	1 90	4.70	7.37
" " "	.66	6.40	1.75	4.65	7.60
" Drone "	.93	10.75	3.55	7.20	4.52
" " "	.90	11.25	3.50	7.75	4.32
" " "	.88	9.90	2.80	7.10	4.91
Extra Thin "	1.25	11.90	2.75	9.15	4.08
" " "	1.22	10.61	2.33	8.28	4.58
" " "	.73	7.15	3.12	4.03	6.80
" " "	.60	7.15	3.07	4.08	6.80
Thin Super (A) "	1.25	13.00	2 40	10.60	3.74
" " " "	1.25	11.50	2.60	8.90	4.23
" " " "	1.20	11.50	3.00	8.50	4.23
" " " "	1.00	10.20	2.80	7 40	4.77
" " " "	.25	5.80	2.70	3.10	8 38
" " (B) "	.90	11.50	4.00	7.50	4.23
" " " "	.75	9.40	3.30	6.10	5.17
" " " "	.75	9.35	2.90	6 45	5.20
" " " "	.75	9.10	2.70	6.40	5.34
1898 Deep Cell "	1.46	16.80	3.60	13.20	2.89
" " " "	1.44	16.63	3.70	12.93	2.92
" " " "	1.13	14.90	3.30	11.60	3.26
" " " "	.56	10.25	3.40	6.85	4.74
" " " "	.50	10.00	4.00	6.00	4 86
1899 " " "	1.50	14.50	2.83	11.67	3.32
" " " "	1.31	13.33	3.33	10.00	3.65
" " " "	.75	11.51	3.74	7.77	4.23
" " " "	.31	6.00	3.00	3.00	8.10
Medium Brood "	1.30	19.50	6.87	12.63	2.49
" " "	1.20	19.12	6.12	13.00	2.54
" " "	1.06	16.50	6.23	10.26	2.95
" " "	1.00	16.50	5.50	11.00	2.95
" " "	.75	12.00	5.35	6.65	4.05
" " "	.75	13.00	5.20	7.80	3.74
" " "	.38	7.50	3.50	4.00	6.48
*Very Heavy "	1.00	18.50	7.00	11.50	2.63
" " "	.95	18.33	8.00	10.33	2.65

* This line is an average of pieces composing 15 square inches of comb.

In the preceding table all the weights obtained from the pieces of comb are given.

The first fifteen examples in the table are of worker comb as built by the bees in the natural way. The three following are naturally built drone comb.

The extra thin foundation weighed but 3.60 grains to the square inch, or 13.50 square feet to the pound, and had very slight cell walls. It is shown at *l* of Plate 2 in cross section.

The foundation listed as "Thin Super (A)" weighed almost exactly four grains to the square inch, or a trifle more than twelve square feet to the pound, and was rather firm in texture. It is shown in cross section at *j* of Plate 2.

That listed as 'Thin Super (B)" was of the same weight as the preceding, but of softer texture and had more wax in the midrib and less, almost none, in the short walls. It is shown in cross section at *f*, Plate 2.

The "1898" deep-cell foundation is the kind shown at *d* of Plate 4. It ran about 5.46 grains to the square inch, or approximately, nine square feet to the pound.

The "1899" deep-cell foundation is that shown in Figure *g* of Plate 4, and it weighed 5.10 grains to the square inch or 9.53 square feet to the pound.

The medium brood foundation weighed 8.40 grains to the square inch, or 5.80 square feet to the pound. It is shown at *c* of Plate 2.

The very heavy foundation averaged 11 grains to the square inch, or 4.42 square feet to the pound, and is shown at *a*, Plate 2.

The thickness of the comb samples in each case is given in the second column in the table, and is stated in inches and hundredths.

The third column gives the weights in grains to the square inch of the samples used, and is the sum of the weights in columns four and five, which give the weights of the midribs and the cell walls respectively.

The column at the right gives the number of square feet of each sample of comb that would be required to weigh one pound.

Each sample was of whole comb, *i. e.*, comb drawn to a greater or less thickness but not capped, so that the cells were complete as built.

It would have been better, or at least easier, to compare samples of comb of the same thickness; but comb varies so much in this respect that it was found impossible to do so with the samples at hand in the experimental apiary, and the evidence desired seems to be fairly ample in the data obtained and given in the preceding table.

First, I will call attention to the fact that the three samples of drone comb, varying between .88 and .93 of an inch in thickness,

are considerably heavier than samples of natural worker comb of approximately the same thickness.

The sample of comb 1.25 inches thick on extra thin super foundation is but .10 of a grain heavier than the average of the two samples of natural comb of the same thickness. The sample 1.22 inches thick is fully as light in proportion to its thickness. The two thinner comb samples on this foundation do not compare quite as favorably with the natural.

The thickest sample of natural comb measured 1.37 inches, and weighed 13 grains to the square inch. No sample on artificial foundation as thick weighed so little, while one sample 1.25 inches thick on thin super foundation (A) weighed the same. All samples over .75 of an inch thick on medium brood and very heavy foundations weighed from about one-fourth to two-thirds heavier, or from 16.50 to 19.50 grains to the square inch. The sample 1.13 inches thick on deep-cell foundation put out in 1898 exceeds in weight the thickest sample of natural comb by 1.9 grains to the square inch.

The samples of natural comb 1.34 and 1.33 of an inch thick are also exceeded in weight by the same thinner samples of comb on artificial foundations just mentioned.

The heavier sample of natural comb measuring 1.25 inches thick is exceeded in lightness by one sample of comb on thin super foundation of the same thickness, while the other sample of the latter is heavier than the natural.

The two thickest samples of comb on "1898" deep-cell foundation average one-seventeenth thicker than the thickest sample of natural comb, but their weights average more than one-fourth heavier than those of the latter. Their comparsion with the next two samples of worker comb would be still less favorable to the foundation.

The sample of natural comb measuring 1.13 inches thick seems not to be unusually light, as the sample 1.15 thick weighed no more; the one that was 1.18 thick hardly exceeded it, and the one 1.20 thick weighed even less. Comparing this comb with the sample of the same thickness on the "1898" deep-cell foundation, we find the latter is heavier than the former by more than one-half the weight of the natural comb. In other words, it is heavier than the natural comb by almost exactly the weight of the deep-cell foundation. The two samples of comb on this foundation that are .60 and .56 of an inch thick respectively are as heavy or heavier than any of the samples of natural worker comb measuring from 1.20 inches in thickness down.

The "1899" deep-cell foundation produced a comb much nearer the natural in lightness. Comparing the sample 1.50 inches thick with the natural sample 1.37 thick, we see there is but 1.50 grains difference in weight, which would be fully accounted for by the greater

thickness of the comb in the case of the latter. Comparing with the two thickest samples of comb on the "1898" deep-cell foundation, either of which is thinner than the "1899" sample, we notice that the latter is, nevertheless, considerably lighter in weight.

If we compare the sample of comb 1.31 inches thick on the "1899" deep-cell foundation with the samples of natural comb measuring 1.33 and 1.35 inches respectively, we find a good margin of difference in favor of the natural samples, although they are somewhat thicker than the example on foundation.

These comparisions bring us again to the conclusion that, of the samples of foundation that we have studied, the thin and extra thin super, and the "1899" deep-cell foundations, are far the best for the production of a comb to compare in quality and lightness with natural comb.

* Now, if we examine columns four and five we shall see that the increased weights of the examples of comb on artificial foundations were due more to the extra wax in the cell walls than to the increased amount of wax in the midribs in cases of the heavy foundations, but not in cases of the thin and extra thin super, or "1899" deep-cell foundations. I will call attention to a few examples and the reader may compare others.

Beginning with the heaviest foundations first, it will be seen that the comb cells in the sample one inch thick weighed 11.50 grains, against 7.50 grains in the case of the natural comb of the same thickness. In case of comb one inch thick on medium brood foundation, the cells weighed 11.00 grains to the square inch.

Take the samples of the same kinds of comb that are .75 of an inch in thickness and the weights of cell walls are, for natural comb, 4.70 grains; for comb on medium brood foundation, 6.65 grains; and for comb on very heavy foundation, 7.80 grains. It will also be noticed that the two samples of comb on "1898" deep-cell foundation that were less than .75 of an inch thick had cell walls that were considerably heavier than the natural comb that was of that thickness.

If we combine the two samples of medium brood comb, one measuring 1.30 and the other 1.20 inches thick, we shall have an average of a sample 1.25 inches thick, the cells of which weigh 12.81 grains to the square inch. Comparing this with the weights of the cells of the natural comb samples of the same thickness, we find it exceeds the heavier by 2.31 grains, and is almost one and one-half

* In "A, B, C of Bee Culture," p. 67, Mr. E. B. Weed is reported to have discovered "That in ordinary foundations upon the market, there was too much wax in the base (midrib) and not enough in the wall; that whenever the base is thicker than the bees make it they will rarely take the trouble to thin it down; but, no matter how thick the wall, they will invariably thin it down to the thickness of the natural." Both these statements need to be much modified, according to the experiments here reported.

times the weight of the lighter. It even exceeds the weight of the thickest of the natural comb samples by 2.01 grains.

If we take the comb cells on "1898" deep-cell foundation that measured 1.13 of an inch thick and compare their weight with the sample of like thickness of natural comb, we see that the cells of the latter are lighter by 4.38 grains. In fact the cell walls of this sample of deep-cell foundation exceed in weight any of those of the seven thicker samples of natural comb.

The comb samples on the "1899" deep-cell foundation had cell walls that compare very favorably with the natural comb in lightness. The comb 1.31 inches thick on this foundation had cells that weighed exactly the same as cells of natural comb that was 1.33 inches thick, and the cells from the sample 1.50 inches thick did not weigh more than would be expected for natural comb. The sample of comb .75 of an inch thick on this foundation does not compare so favorably in weight of its cells.

If we pass to the comb on thin super foundations we again find very satisfactory comparisons. The cells from comb 1 inch thick and from comb 1.20 inches thick weighed only a trifle more from the foundation than from natural comb. The same is true of the average of the two samples in each case that were 1.25 inches thick. The differences being so slight, go to show that there is practically no difference in the weight of cell walls of natural comb and comb of the same thickness on the thin super foundation.

The samples of comb on extra thin foundation compare equally well with natural comb in the lightness of their cell walls, as may be seen by the table.

By comparing the weights of the comb midribs given in column four, it will be seen that the lightest midribs from comb on foundation are not quite as heavy as the heaviest midribs in natural worker comb, but in every case they are heavier than the average weight (2.10 grains to the square inch) of the midrib of natural comb.

With this additional evidence, it seems impossible to avoid the conclusion that heavy foundations result in combs heavier than the natural, and that the increased weight is due both to thicker midribs and heavier cell walls, but much more to the latter than to the former in cases where heavy foundations are employed, even though much wax is left unused in the midrib.

The experiments show that to get a light comb, approaching that which the bees naturally build, there must not be a large amount of wax in either the midrib or cell walls of the foundation.

The evidence is also quite conclusive that if the cell walls are very high, as in the "1898" deep-cell foundation, they will not often be well thinned in the building of the comb.

TO WHAT EXTENT DOES THE FOUNDATION LESSEN THE SECRETION OF WAX BY THE BEES?

Let us begin with the comb built on the heavier foundations and compare with the naturally built worker comb, to determine the effect on wax secretion.

Natural worker comb 1 inch thick weighed 10.00 grains to the square inch. The very heavy foundation alone weighed 11.00 grains, or 1 grain more than is necessary to build the comb to that thickness. But when comb was built on this thick foundation, it weighed 18.50 grains, so that the bees added 7.50 grains to the square inch to the foundation that itself contained more wax than was necessary to build the comb. As natural comb weighs but 10.00 grains to the square inch, the bees lacked but 2.50 grains of furnishing as much wax as they would have done if they had built the comb without the foundation. *It is seen that 11.00 grains of wax were furnished the bees in order to save them the expense in food and labor of producing 2.50 grains.

In case of the medium brood foundation weighing 8.40 grains to the square inch, the result was similar. The bees needed to add but 1.60 grains to this to build the comb one inch thick, but they did add 8.10 grains, making a comb weighing 16.50 grains to the square inch. As the amount added in this case is only 1.90 grains less than the weight of the natural comb of the same thickness, it cost the whole weight of the foundation, or 8.40 grains, to save the bees from secreting 1.90 grains of wax.

As another illustration with this same foundation, take the samples drawn to .75 of an inch. The average weight would be 12.50 grains. This is 5.90 grains more than the weight of samples of natural comb drawn to the same thickness, and 4.10 grains more than the weight of the foundation alone, notwithstanding the fact that the foundation as given the bees contained 1.80 grains to the square inch more wax than was necessary to build natural comb to that thickness. In other words, the bees were furnished more wax than was necessary to build the comb three-quarters of an inch thick, and yet they added to this amount more than nine-tenths as much wax as they would have used to build the comb without foundation.

Passing now to the Weed deep-cell foundation manufactured in 1898, we find results fully as surprising. If we compare the sample measuring 1.13 inches thick with natural comb of the same thickness, we find that the latter is lighter by 5.35 grains. As the foundation itself weighed only 5.46 grains to the square inch, the indication is that the bees used as much wax from their own secret-

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* Cheshire says "Bees very rarely work more than half their cell walls out of even the stoutest sheets given them." –*Bees and Bee Culture*, V. II., p. 216.

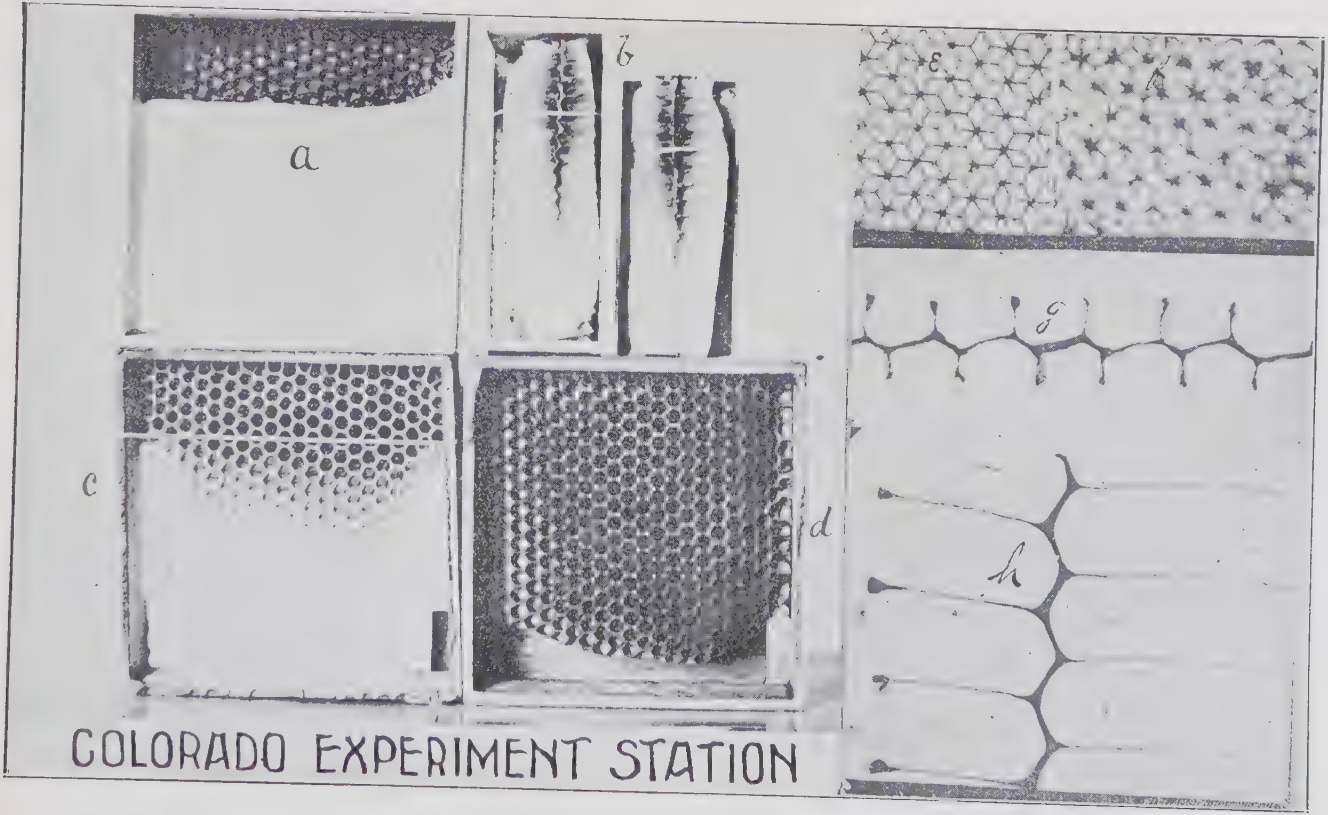

PLATE 1.

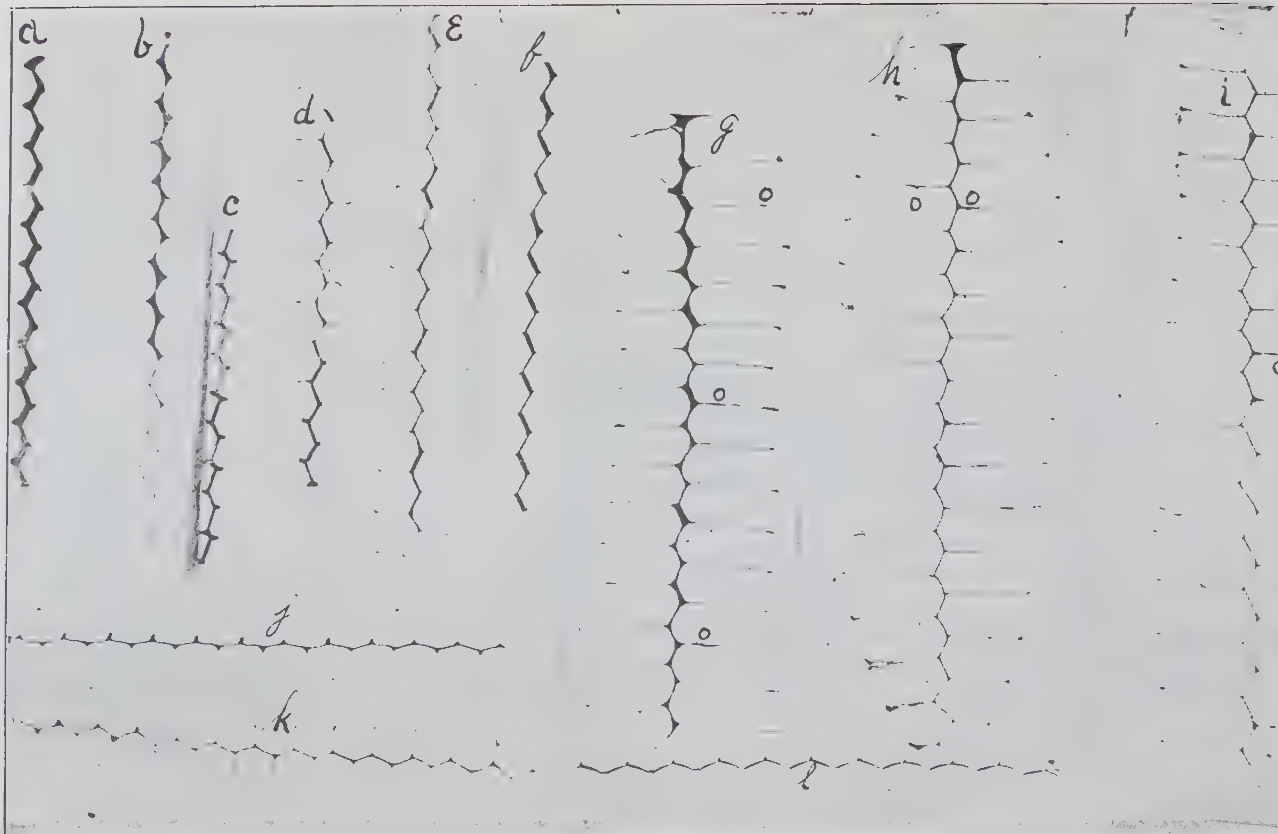

PLATE 2.

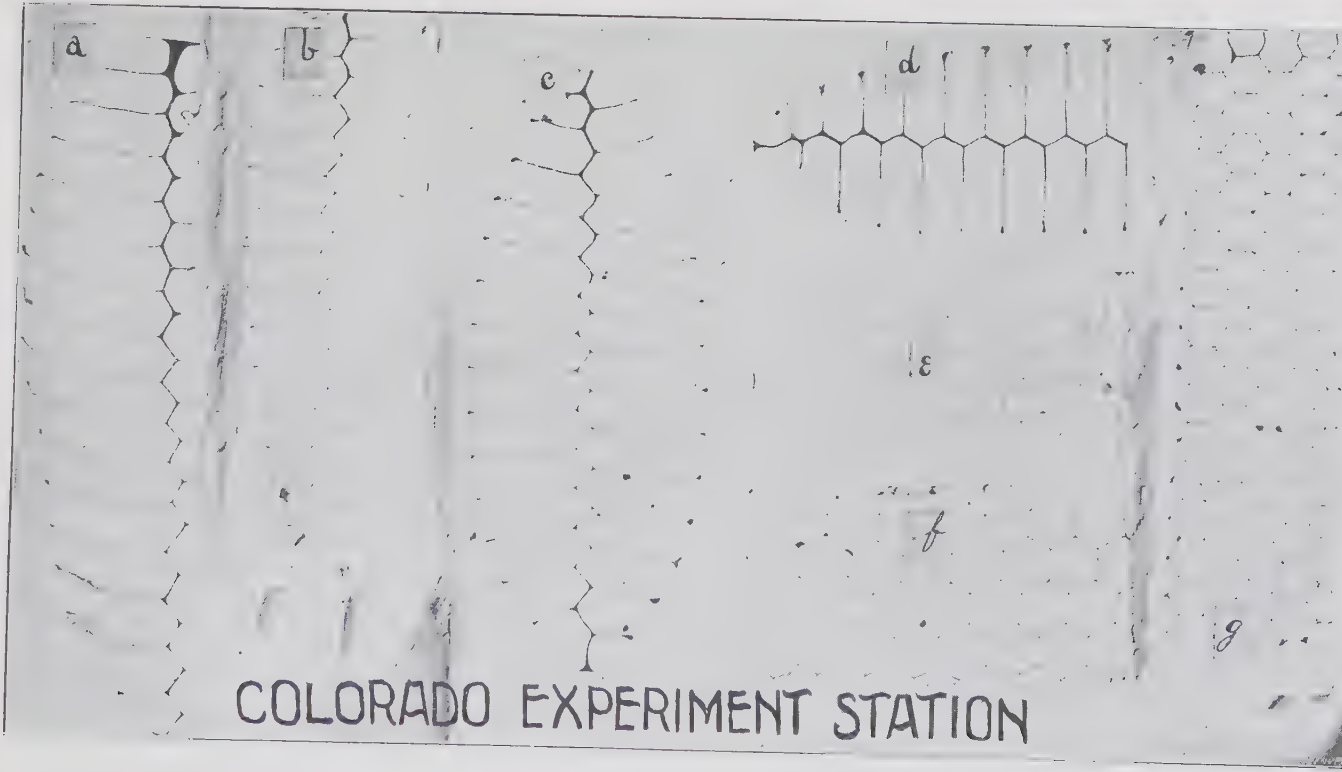

Plate 3.

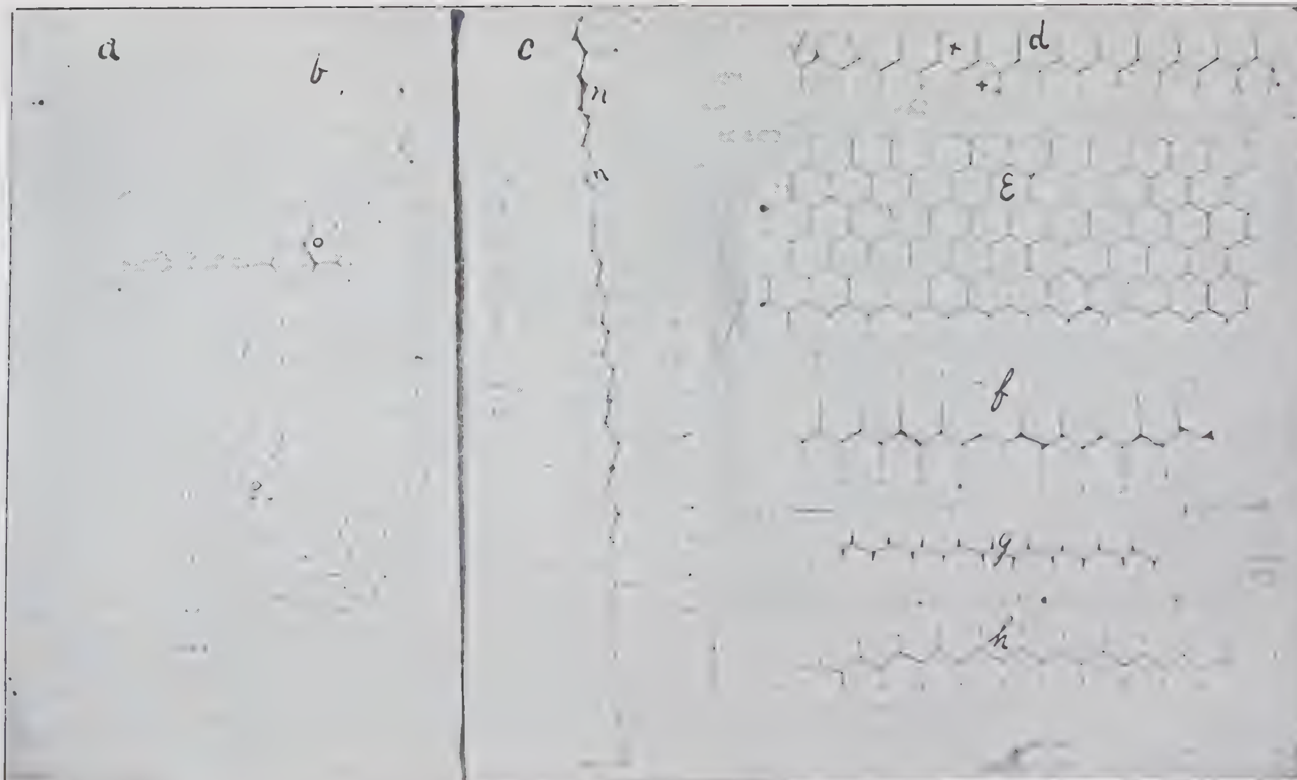

PLATE 4.

ing within .11 of a grain, as they would have done if no foundation had been given.

The samples of comb .56 and .60 of an inch thick on this foundation contain enough wax to make a natural comb one inch thick, and nearly half of the weight was added by the bees.

Reliable results are not so readily obtained in the study of comb samples on the light foundations, as the amount of wax in them is small and the natural variation in comb samples is considerable.

The thickest sample on the thin super foundation (B) was only .90 of an inch. To get as near an average weight of the natural comb as possible for comparison, let us combine the two examples that measure .90 of an inch each with those measuring respectively 1.00 and .80 of an inch. The average would be 8.40 grains to the square inch. The difference between this and the sample on this foundation is 3.10 grains. As the foundation itself weighed 4.00 grains to the square inch, the indication in this case is that the saving to the bees was the difference between these weights, or .90 of a grain to a square inch, or about 23 per cent. of the amount of wax given.

Far better results were obtained in the use of thin super foundation (A), the average weight of which was 4.07 grains to the square inch.

Comparing comb 1 inch thick on this foundation with natural comb of the same thickness, we find, in case of one of the samples in the table, there is but .20 of a grain difference in favor of the latter. This means that this foundation lessened the amount of wax that the bees secreted, by 95 per cent. of its own weight.

The above may have been rather an exceptional piece on the thin foundation. If we compare the sample that measured 1.20 inches in thickness with a similar sample of natural comb, we find a difference of 2 grains to the square inch. As the foundation was almost exactly twice this weight, it indicates that the bees were relieved from secreting an amount of wax equal to half the weight of foundation given.

It is important to notice that to build the comb on this foundation to the thickness of 1.20 inches, the bees added the difference between 11.50 and 4.07 grains to the square inch, which would be 7.43 grains, and this is actually less than they added in cases where they built comb to a thickness of only one inch on the very heavy and the medium brood foundations, and to a thickness of 1.13 inches on the deep-cell foundation, though in any one of these last three cases they were furnished more wax to start with.

Again, if we take the average of the two samples of comb on this thin foundation that were 1.25 inches thick and compare it with an average of the two samples of natural comb of the same thickness, we find that the latter is .40 of a grain lighter to the square inch

than the former. This would indicate that 90 per cent. of the foundation was utilized by the bees in making a comb but slightly heavier than the natural. We also find that the bees actually added less to this foundation in order to draw it out to 1.25 inches in thickness than in cases where they built comb to a thickness of an inch on the heavy and medium brood foundations. Further experiments are needed bearing upon this point.

If we compare the comb built on the "1899" deep-cell foundation and the extra thin super foundation with the natural comb, we find results nearly, or quite as good as the preceding. For examples, the comb 1.31 inches thick on the deep-cell foundation was but 1.13 grains heavier than the natural sample 1.33 inches thick, and the sample on this foundation that was 1.50 thick exceeded the weight of natural comb 1.37 inches thick by only 1.50 grains.

In case of the comb on extra thin foundation, the sample that was 1.22 inches thick weighed but 1.11 grains to the square inch more than the natural sample that measured 1.20 inches thick; and the sample on this foundation 1.25 inches thick is almost exactly an average of the two pieces of natural comb of the same thickness.

It seems, then, from all the evidence furnished by the forty-nine samples of comb listed in the preceding table, that we do not lessen the wax secretion of the bees much, if any, more when we furnish them a heavy foundation than when we furnish them a very light foundation.

These differences between the heavy and light foundations for comb building seem quite remarkable, and in a large series of samples might not result so much in favor of the light foundations; but the samples recorded in the table were taken without any attempt or thought of favoring one form or weight over another.

The writer believes it is a matter of much importance to beekeepers to produce comb honey with as small an amount of wax as possible. They will, in this way, increase the consumption of their product, as many people object to comb honey because of the large amount of wax they often find in it.

METHODS OF USING FOUNDATION IN SECTIONS.

It is necessary to use some foundation in sections for comb honey. The best size and form of the piece of foundation to be used as a "starter" is not universally agreed upon, some preferring one form and some another.

The different methods of applying these starters, shown in Figures *a* to *g* of Plate VI., have been tested in the College Apiary for the past three years.

There was no appreciable difference in the comb produced by using starters in the manners shown by Figures *a*, *c* and *d*. The only advantage in the long, narrow piece, shown at *e*, was that it had

a tendency to secure the building of worker comb throughout. It has one disadvantage, and that is its large size and short line of attachment, so that if it is not well secured at the top the bees are liable to cluster upon it and pull it loose. The long, narrow piece placed across the top of the section, Figure *f*, has given rather better results than any of the preceding, as the bees usually attach it quickly at the ends, thus closing the top corners. I have also used many starters like the preceding, but extending about half way down. Figures *h*, *i* and *j* represent comb on such starters. It will be noticed there are no holes in the upper corner or sides. At *n* is a section of comb built on a full-sized starter, as shown at *g*. It will be noticed that the comb cells are all uniform in size and the comb evenly filled out. Such comb when filled and capped, is handsome in appearance, like the samples shown at *s*, and brings the highest market price. In my experiments the sheets that extended half way down gave as good results as those that filled the section. The use of small pieces of foundation in the lower corners, as shown at Figure *c*, gave no beneficial results.

The use of short strips of foundation in the middle of the bottom of the section, as shown at *b*, has resulted in somewhat better attached combs at the bottom of the section, especially during a slow honey flow.

Figures *k*, *l* and *m* show how comb is usually extended from a small piece of foundation, leaving, very often, holes in both upper corners. If the honey is coming in slowly and the colony is not very strong, the sections are liable to be finished like the two shown at *o* and *p* of the same plate. Not only are these sections light in weight and slow to sell, but they will not ship well, for the jar of handling will break many from their attachments in the sections. I have found, however, that such sections of honey are due much more to a weak condition of the colony and a poor honey flow than to the manner of using foundation. Under such conditions even large pieces of foundation are often gnawed away, as shown at Figures *q* and *r*. When the colony is strong and the honey flow good, small pieces of foundation, like the one shown at *a*, will often produce just as finely filled sections as can be obtained from full-sized pieces with strips below. Moral: Keep the colonies strong.

Comb built upon foundation is always tougher and more waxy than the natural comb, and a cross-section will show that the midrib and bases of the cells are darker in color. So that while the large pieces of foundation result in a somewhat finer appearing capped honey, the small starters will result in a more delicate and brittle comb.

ADVANTAGES FROM THE USE OF SEPARATORS.

Most producers of comb honey recognize the advantage in the use of thin strips of wood or tin between the rows of sections in the

supers. Without them the comb is sure to be uneven in a large proportion of the sections, and in many cases it will be bulged so as to make it very difficult to pack the sections in a crate for shipment. Illustrations of such sections are shown at *h* of Plate 5. These sections also vary much in weight, some weighing considerably more than a pound, while others weigh as much less. They are not as attractive nor as easily handled upon the market as those that are built with flat faces that do not project beyond the edges of the section, and that are all uniform in weight and appearance, as shown at *s* of Plate 6. I have used the tin and board separators in about equal numbers and have been unable to see that one has any special advantage over the other.

I have also used separators upon one side and upon both sides of the sections. While very good sections of honey are obtained by the use of separators upon one side only, the results have been enough better when used upon both sides to make the latter plan advisable. In my experiments the sections that had no separators averaged one-half ounce more in weight than those with separators on one side only, and the latter weighed one-half ounce more than the sections that had separators on both sides. As these lighter, better appearing sections sell better than the heavier, ill appearing ones, there is a double advantage in their production.

PROPORTION OF WAX IN COMB HONEY.

Beeswax does not melt at the temperature of the body and is indigestible in the human stomach. Although this does not necessarily imply that beeswax is harmful in food, it becomes a matter of some interest to know how much wax is taken with ordinary comb honey when the latter is eaten. It is also a matter of interest to know how much wax the bees are compelled to secrete for every pound of honey that they store in the natural way.

As a thick comb has but one midrib, and as the walls of the cells are heavier near the midrib than they are towards their outer portions, it is evident that comb one and one-half inches thick would not be half heavier than comb one inch thick. The increased weight of the thicker comb would be due entirely to the additional wax required to extend the walls of the cells one-half inch, and to that only. On the other hand, it is equally evident that the honey filling a comb one and one-half inches thick would weigh half more than honey filling a comb one inch thick. Consequently the weight of wax in thick combs is less in proportion than in thin combs. The weights given in the following table shows this to be true:

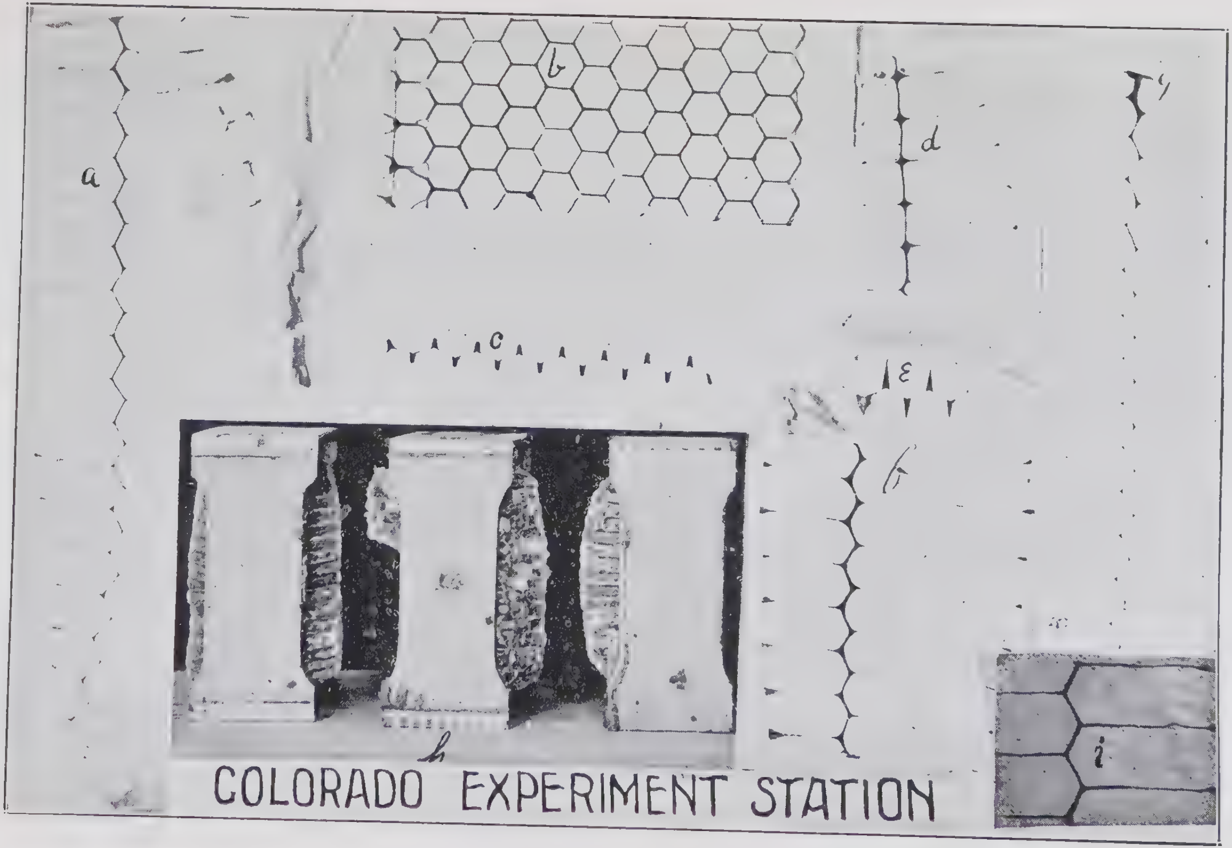

PLATE 5.

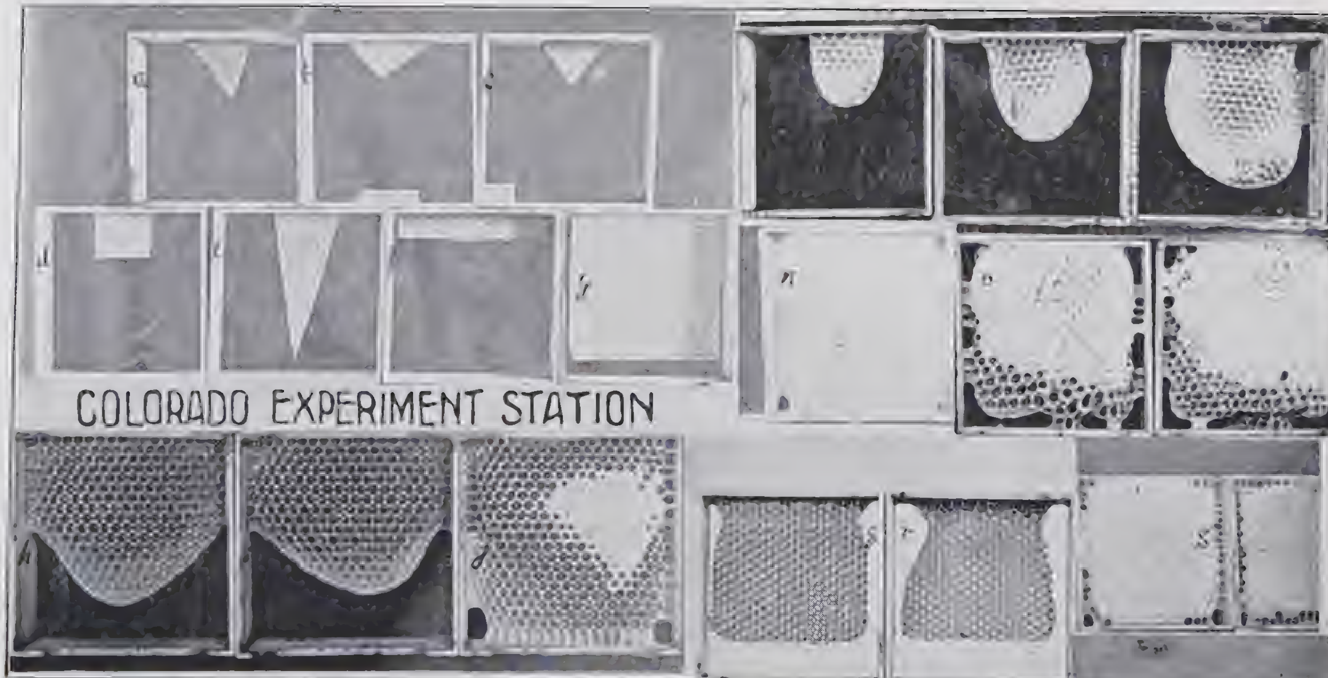

PLATE 6.

Table Giving the Proportionate Weights of Honey and Wax in Capped Comb Honey.

KINDS OF COMB.	Thickness in Inches.	Total Weight in Grams.	Weight of the Honey in Grams.	Weight of Wax only in Grams.	Proportion of Wax to Honey.
Natural	1.37	308.45	297.95	10.50	1 to 28.38
"	1.13	174.00	167.71	6 29	1 to 26.66
"	.75	75.00	71.14	3.86	1 to 18.43
On Small Starter	....	374.00	356.76	17.24	1 to 20.70
" " "	....	351.00	334.40	16.60	1 to 20.02
" " "	....	346.00	330.40	15.60	1 to 21.12
" " "	....	344.20	328.50	15.70	1 to 20.92
" " "	....	344.00	328.19	15.81	1 to 20.76
" " "	....	312.80	298.00	14.80	1 to 20.13
" " "	....	287.00	273.20	13.80	1 to 19.80
On Full Piece '99 Deep-Cell Starter	.. .	544 00	525.08	18.92	1 to 27.75
On Full Piece '98 Deep-Cell Starter	....	4[illegible]4.00	381.00	20.00	1 to 19.70

In case of natural comb honey 1.37 inches thick the honey weighed 28.38 times as much as the wax, while the sample .75 of an inch thick, which was built at the same time as the thicker comb and by the side of it, had only 18.43 times as much honey as wax. The intermediate sample (1.13 inches thick) had 26.66 times as much honey as wax.

All other comb samples in this table were taken from sections measuring $4\frac{1}{4}$x$4\frac{1}{4}$ inches and $1\frac{3}{4}$ inches thick. The combs were built on small top starters, except in case of the last two examples, one of which was built upon a full-piece of the "1899" deep-cell foundation and the other upon a similar sheet of "1898" deep-cell foundation. The thickness of the comb was not taken in these sections, but it did not vary much from one and one-fourth inches in any case.

The comb in the sections with small starters did not vary much from one-twentieth of the weight of honey in any case, and the proportion of wax was somewhat greater than in the samples of natural comb of similar thickness.

Passing to the sample of comb on the "1899" deep-cell foundation, we notice, first, that it is much heavier than any of the preceding, and hence much thicker, and in consequence it has a much higher ratio of honey to wax, 1 to 27.75. This is also in keeping with results announced on previous pages, indicating that this

foundation is drawn out by bees into a comb approximating the lightness of the natural product.

In contrast to this last example, but also in harmony with results given on preceding pages, notice that the "1898" deep-cell foundation gave a comb heavier than the preceding, though the honey weighed less by more than one-fourth. The proportion of wax to honey was greater in this case than in any of the others, except that of natural comb only .75 of an inch thick. It should have given a larger proportion of honey than any of the samples built on small starters, as the comb in the latter was thinner in every case.

From the facts given in the above table, it is evident that if we are to secure a comb honey with the least possible amount of wax, it will be necessary to have it built in sections that will secure the greatest thickness of comb. In this way we can also economize very considerably the labor and energy of the bee in wax secretion and comb building.

Attention might also be called to the fact that it takes more wax and more work for the bees to cap ten pounds of honey in thin comb than in thick comb.

The reader will not understand that I am advocating the use of deep sections; there may be other reasons why they are not preferable; I am only mentioning points which, according to my experiments, favor thin sections.

SUBSTITUTES FOR POLLEN.

It is a well known fact among bee-keepers that bees can be stimulated to early brood rearing in spring by putting out some kind of finely ground meal or flour, which they take as a substitute for pollen. Writers vary in their opinions as to what is the best, but it is commonly recommended to use rye, oats, or pea meal. Common wheat flour, wheat middlings, corn meal, barley meal, and malt all have their advocates. It was thought best to put out at one time a good number of these substitutes for the purpose of determining which would be given the preference by the bees. To do this a number of boards were laid flat upon the ground in the vicinity of the apiary, a small pile of each kind of meal put upon them and notes taken upon the results.

It was found that any of the substances used would be taken freely when used alone. Also that the preference did not always go to the same feed.

Results with the first series of tests were published in the Seventh Annual Report of this Station. As that report did not reach a large number of general readers, and as subsequent tests lead to some change in the order of preference, I have thought it best to report upon the work again here. The order of preference as nearly as could be judged ran as follows: Ground whole kernels of oats, corn, and wheat, fine wheat bran,* cleaner dust,† cotton-seed meal, wheat bran, pea meal, wheat flour, rye flour, bean meal, barley meal. The three last named they would hardly touch as long as others were accessible.

As pollen furnishes the bees with nitrogenous food, it seems probable that those substitutes for pollen that have most nitrogen, or rather, that furnish the chemical compounds most nearly in the proportions that they are found in pollen, would be best suited to take the place of pollen in the dietary of the bee.

In order to determine whether or not the chemical composition of the food-stuffs best liked by the bees were more like the composition of pollen than the others, I had a quantity of corn pollen col-

* Bran ground over so as to be fine.

† Waste dust and chaff as taken from cleaners at flouring mill.

lected and taken to Dr. W. P. Headden, Station Chemist, for analysis. In the table below the first analysis is that of corn pollen made by Dr. Headden, and the analyses of the other materials are compiled:

NAME.	Water.	Ash.	Crude Fibre.	Fat.	Protein.	Nitrogen Free Extract.
Corn Pollen	3.444	5.039	7.970	1.526	19.598	62.423
Oats Ground	9.3	3.5	8.5	3.6	11.4	63.7
Corn "	13.6	1.4	1.9	3.4	9.6	70.1
Wheat "	11.5	2.0	2.9	2.0	12.1	69.5
Wheat Bran	11.0	5.7	10.4	5.0	15.9	52.0
Cotton-seed Meal	8.0	6.9	6.7	10.0	42.0	25.7
Pea Meal	8.8	2.6	17.7	1.6	19.2	50.1
Wheat Flour	12.6	0.7	0.7	1.2	11.8	74.1
Rye Flour	14.0	1.6	1.5	1.6	10.5	72.5
Bean Meal	12.0	1.4	2.1	8.5	11.0	65.0
Barley Meal	13.1	2.4	5.7	1.9	11.3	65.6

It will be noticed that, while the nitrogenous material (protein) is high in the pollen, it is not very high in some of the flours best liked by the bees, as for example, corn and oats. Cotton-seed meal runs very high in protein and was not specially liked.

So there are, doubtless, other reasons than the amount of nitrogenous food material, that influence the bees to take substitutes for pollen. It is probable that the aroma and mechanical qualities may have much to do in determining their choice. There is nothing very definite in the above order of choice of the different foods used. The order will often vary on consecutive days, or even on consecutive hours.

It is by no means certain that the flour the bees like best is best for them, for this manner of supplying them nitrogenous food is entirely artificial. The best substitute for pollen is that food which the bees will take and upon which they do best, and it seems probable that it will have a chemical composition approximating that of natural pollen.

SUMMARY OF MORE IMPORTANT CONCLUSIONS.

1. Bees use freely the wax in foundation to extend both the midrib and the cell walls of honey comb.

2. The heavier the foundation used, the heavier, as a rule, will be the comb built upon it.

3. If the midrib of a foundation is much lighter than that of natural comb, the bees are likely to strengthen it by adding wax to the bottom of the cells.*

4. If the midrib of the foundation is thicker than the midrib of natural comb, it will result in a comb with a midrib thicker than the natural. Or, to state it differently, the bees will not thin the midrib of a foundation down to the thickness of worker comb built in the natural way.

5. Midribs of foundation that are not more than .17 of a millimeter (.007 inch) in thickness, are thinned little or none by the bees.

6. Drone comb has a thicker midrib and heavier cell walls than worker comb.

7. A foundation with a heavy midrib and very slight cell walls, will still produce a comb with heavy cell walls.

8. Very high cell walls in foundation are not cut down to the thinness of cell walls in natural comb.

9. The thin and extra thin and the "1899" deep-cell foundations produce a comb that approximates very closely the lightness of that which is naturally made by the bees.

10. When heavy foundations are used, the extra weight of the comb built upon them is due more to the extra weight of the cell walls than to the heavier midrib.

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* Possibly this is only done where there are actual perforations of the comb.

11. When very light foundations are used, the somewhat heavier comb is due almost entirely to the midrib being heavier than that of natural comb.

12. When foundations containing an abundance of wax to build the entire comb are used, the bees still add much more wax, sometimes nearly enough to build the comb without the help of the wax in the foundation.

13. Wax seems to be given with the best economy when the midrib of the foundation is of the thickness of the midrib of natural comb, and when there is a small, or at most a moderate, amount of wax in the cell walls.

14. Poorly attached combs in sections seem to be more the result of weak colonies and poor honey flow than to the kind of starter that is used; though large starters and strips of foundation in the bottom of the sections do help to strengthen the union of comb to the section.

15. Separators between the sections are essential to the best results in producing comb honey.

16. The thicker the comb, whether natural or artificial, the greater the proportion of honey to wax in it.

17. In natural worker comb, one inch thick, the proportion of wax to honey is between 1 to 20 and 1 to 25 by weight.

EXPLANATION OF PLATES.

Plate 1.

a, blackened super foundation; *b*, sections of comb built on a strip of blackened foundation as shown at *a*; *c*, comb built on narrow strip of foundation as shown at *a*; *d*, fully drawn comb built on full-piece starter of black foundation; *e*, midrib of natural worker comb after removing the cells; *f*, midrib of comb built on "1898" deep cell foundation; *g*, comb that the bees have just begun to draw on medium brood foundation, enlarged about two diameters; *h*, like the preceding except that the cells are fully drawn.

Plate 2.

a, cross-section of very heavy foundation; *b*, midrib of comb built on very heavy foundation in upper two-thirds, the lower third being natural midrib extended by the bees; *c*, cross-section of medium brood foundation; *d*, like the preceding except that the bees had begun to draw out the cells in the upper two-thirds of the figure; *e*, the same as *d* with the cells farther drawn; *f*, a rather heavy super foundation blackened with lamp-black; *g*, section of comb on heavy foundation shown at *a*; *h*, comb on foundation shown at *f*; *i*, the upper two-fifths like *h* and the remainder natural drone comb; *j*, section of thin super foundation; *k*, the same as the preceding with the cells partly drawn; *l*, section of extra thin foundation.

Plate 3.

a, section of comb on thin foundation in upper half, natural comb in lower half; *b*, natural comb; *c*, natural comb cut from side to side of a section of honey; *d*, comb built on "1898" deep-cell foundation; *e*, cells of natural worker comb cut in cross-section; *f*, cells of natural drone comb in cross-section; *g*, cells of worker comb in cross-section, the upper one-third of which was built on the foundation shown at *f* of Plate 2, and the rest is natural.

Plate 4.

a, cross-section of comb cells, the upper third of which were built on "1898" deep-cell foundation; *b*, cross-section of worker

comb built on very heavy foundation; *c*, section of comb built on "1898" deep-cell foundation; *d*, section of "1898" deep-cell foundation; *e*, cross-section of the cells of "1898" deep-cell foundation before being worked by the bees; *f*, section of comb on the "1898" deep-cell foundation; *g*, section of "1899" deep-cell foundation; *h*, partly drawn comb on the preceding foundation.

PLATE 5.

a, section of comb on "1899" deep-cell foundation; *b*, cross-section of cell walls of the "1899" deep-cell foundation before they have been worked at all by the bees; *c*, section of the Weed "thin-base-and-heavy-wall" foundation; *d*, section tnrough comb to show that the midrib can be cut so as to give a straight line; *e*, another sample of comb manufactured by Mr. Weed with extremely thin midrib and high and heavy walls; *f*, comb on medium brood foundation; *g*, comb on extra thin super foundation; *h*, sections of honey showing how comb is bulged when separators are not used; *i*, comb on "1898" deep-cell foundation somewhat magnified, showing the heavy basal portion of the cell walls.

PLATE 6.

a to *g*, different methods of using starters in sections; *h*, *i* and *j*, showing how comb is built on starters that fill the sections half way down; *k*, *l* and *m*, showing method of building down comb from small starter; *n*, comb built on a full-piece starter; *o* and *p*, the way sections are finished in weak colonies or during a poor honey flow, particularly with small-piece starters; *q* and *r*, large piece starters that the bees have gnawed away during dearth of honey; *s*, the way sections should be finished.

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FORESTS AND SNOW

—BY—

L. G. CARPENTER.

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* Died December 9, 1900.

FORESTS AND SNOW

By L. G. CARPENTER.

The intimate connection between the melting snow banks of the mountains and the agricultural prosperity of Colorado is too evident to those acquainted with the conditions of the State to need discussion, for most of the water which carries fertility to the fields and farms comes from the white-capped mountains; but even among those most interested in the agriculture of the State there have been some who have had a question as to the extent to which the forests were useful. Some have even advocated their destruction, under the supposition that the water supply would be increased.

While it is not thought by the writer that the forests materially affect the rainfall in our Colorado mountains, their influence as a protecting cover for the snow and in saving it from premature melting and the effect of winds, which increase the evaporation, is an important function. Without intending to enter upon a discussion of the question at this time, this bulletin is more especially intended to bring out some of the relations of the forests to our water supply, which have become evident in our study of one of the typical irrigation streams, and also to present some of them pictorially, in such form as to help the reader draw conclusions for himself.

For some years attempts have been made to obtain photographs which would show certain conditions, but as visits to the localities in question were usually made for other purposes, the trips were too late to be at the best time to examine the effect of the forests. It was found that it would be necessary to go earlier in order to obtain views desired, and to make trips for that special purpose. Hence, when the heavy snowfall of 1899 gave promise of remaining late enough in the summer to permit visits to the regions without interference with other work, advantage was taken of it. Correspondence had been opened with mountain friends, who with long acquaintance with mountain conditions had had unusual chances for observation. They were asked to let me know when the snow cover had so melted that the ground appeared in places, and also the places where green timber and bare spots were near together, so that the conditions could be readily compared. A portable dark-room was prepared for developing in the field. Reports that the conditions were favorable were received from three correspondents on the same day. The snow fields were melting so fast that only one section could be visited while the conditions were favorable, and this was near

the headwaters of the Cache a la Poudre. Two places, some twenty mile apart, were visited. One on the divide between the Poudre River and Estes Park, and the other on the headwaters of the Laramie River. The former was visited under the guidance of Mr. John Zimmerman, who is a native of Switzerland, and who has lived in the high elevations of Colorado for nearly twenty years; the latter, under the direction of Mr. John McNabb, who has also had a long and intimate acquaintance with high elevations. The results are shown in the plates, which speak for the photographic skill and successful carrying out of instructions by Mr. J. D. Stannard, then assistant in the Department of Engineering. It is believed that no more striking series of photographs on this subject has been brought together. They enable a comparison of the conditions to be made by the reader and repay examination and thoughtful consideration in connection with the charts.

We hoped to obtain an additional series of photographs during the subsequent winter, but the character of the snowfall was unfavorable for this purpose.

A general description of the condition of the streams, as connected with the melting of the snows, is desirable as a basis for the explanation of the views.

CHARACTER OF THE STREAMS.

Colorado is moderately supplied with rain, the annual precipitation averaging about fourteen inches. In the mountain areas, the amount varies with the elevation and topographical conditions, but the increase with elevation is not marked until the extremely high elevations are reached. In these places observations are under exceptional conditions, and too few in number to form a safe guide. On the eastern slope of the mountains, the precipitation is mostly due to the easterly winds brought in by the passage of an area of low barometer to the south. The air is forced up by the mountain ranges, and cooled by the elevation enough to cause condensation and precipitation. Sometimes there are extremely heavy local showers, often called cloudbursts. Much of the precipitation at the higher elevations, even in the summer months, is in the form of snow. June, July and August are practically the only months in the year when rain falls at or above timber line. Snowfalls are not uncommon down to an elevation of 6,000 feet, even in May.

The rain runs off quickly and may immediately influence the streams. The snow remains until it is melted or evaporates. Its effect is gradual, and may thus last for some time. Most of the winter precipitation in the mountains remains on the ground in the form of snow until spring. A portion, sometimes not inconsiderable, evaporates, especially when the snow is porous or soft. It may then be seen to visibly decrease. Heavy winds which blow the snow about increase this loss. Some of the mountain observers say, "The wind just naturally wears it out."

In the case of land denuded of timber the surface is generally hard, and the water runs off rather than penetrates. In the forest areas the soil is looser, more porous and absorbent, and takes up water freely. In such areas springs, or springy soil, are more common, while they are

rarely found in tracts burned over or denuded of timber. It is the water from these springs which maintains the flow of the rivers from September to April. Their decrease is cause for alarm. Within the past few years the Poudre at one time fell to less than forty cubic feet per second. April and May are the months of heaviest rainfall; most of the continued storms occur during these months. Yet, our river records, now carried on for nearly twenty years, show that these rains have comparatively little effect. A rise in the river due to a storm is distinguishable from one due to melting snow, as may be seen from the diagrams. The snows show a daily tide, usually at the same hour. The rises due to storms are irregular in time and character. An unexpected effect is that rains in the mountains usually decrease the amount of water. The cloudiness associated with the storms prevents more thawing than the rain supplies.

If the area covered by snow has been extensive and extends to a relatively low elevation, with the coming of warm weather the snow melts soonest on the low areas. As a rule these are less protected from the rays of the sun. Melting proceeds, even to considerable elevations, in the direct rays of the sun, though freezing may be going on at the same time in the shade, as on the north side of the ridges. A forest cover protects from the direct rays of the sun just as the ridges do.

In the middle of the summer, snow is to be found at moderate elevations only in the forests or under ridges where sheltered from the direct rays of the sun. As melting proceeds the tributaries are swollen, and the main streams increase in volume, their maximum being reached long before the greatest heat of summer. Though the melting is faster, the snow areas are so much less that the aggregate is reduced, hence, the stream decreases.

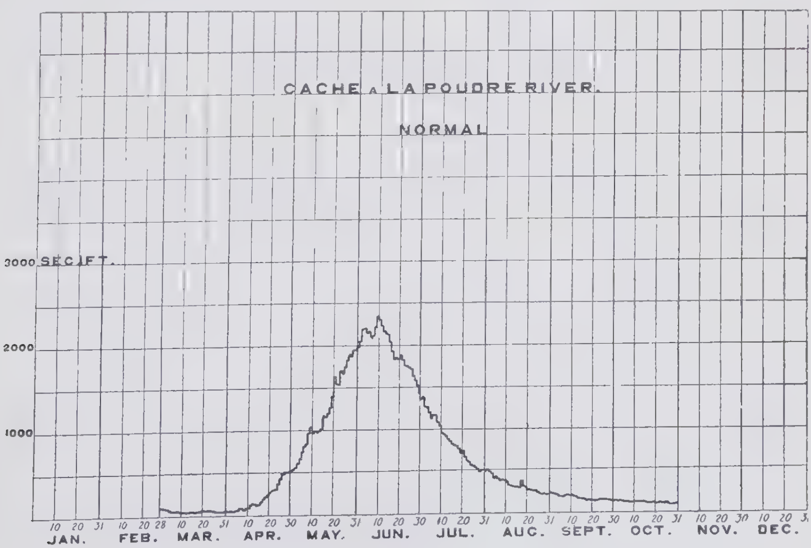

Figure 1.

A typical stream is shown in Fig. 1. This represents the flow of the Cache a la Poudre, on which a longer series of records are available than on any other of the Western streams. The diagram is from nearly twenty years' record of automatic instruments.

The stream is low in fall and winter, when the supply is largely from springs. It rises in April with the rains or melting snows, and more rapidly as the sun and increasing temperature acts on the snow fields.

The rate of rise depends on the area which is covered with snow; on the temperature of night and day; on the dryness of the air, as affecting evaporation; the area of the forest! and the character of the snow, whether it be new and soft or old and hard.

DAILY EFFECT OF THE SUN ON THE MELTING.

A daily rise and fall takes place and is more marked as the river rises. This is shown by the various diagrams. Fig. 2 is a fac-simile of the diagram taken from the instrument during the week from June

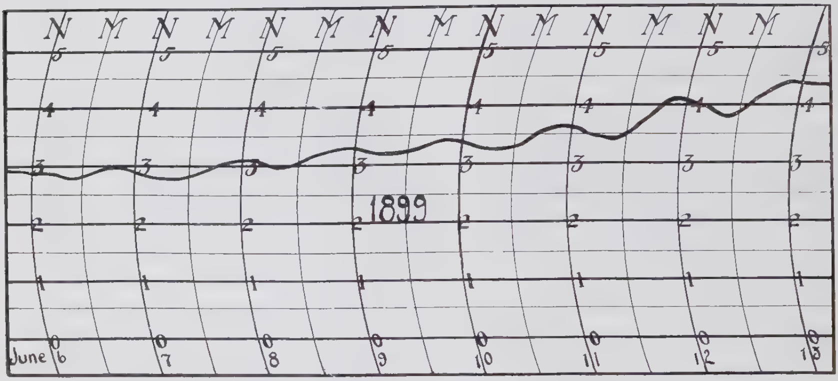

Figure 2.

6-13, 1899. The days are shown at the bottom of the diagram, the gage depths at the left. "N" indicates the noon hour, "M" midnight. The crests of the rises are seen to be twenty-four hours apart. The high water occurs from 4 to 6 a. m. at the point where our instrument is placed, and the low water about 8 p. m. This hour depends on the distance to the snow fields. An examination shows that the extreme fluctuation on June 20-21 was nearly a foot, less on the other days.

When we consider the quantity of water, instead of the depths, this fluctuation appears of more importance. Fig. 4 represents the quantity of water for the same week as shown in Fig. 2. The scale at the left gives the quantities in cubic feet per second. While on the evening of June 20 there was less than 3,000 cubic feet per second, before morning it had become 4,700 cubic feet, falling back to about 3,300 cubic feet during the day, and rising again to 3,900 feet during the night. This diagram is typical of the fluctuation in sunny weather

during high water. The change is clearly connected with the diurnal effect of the sun. It is seen in the other diagrams, but almost disappears in cloudy weather.

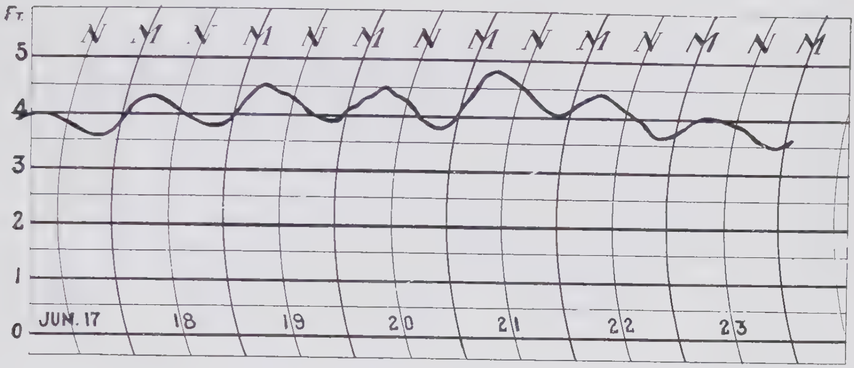

Figure 3.

While the temperature has a marked influence in determining the general stage of the river, the direct action of the sun as shown by the diagrams is still more marked, as it causes these fluctuations. Anything

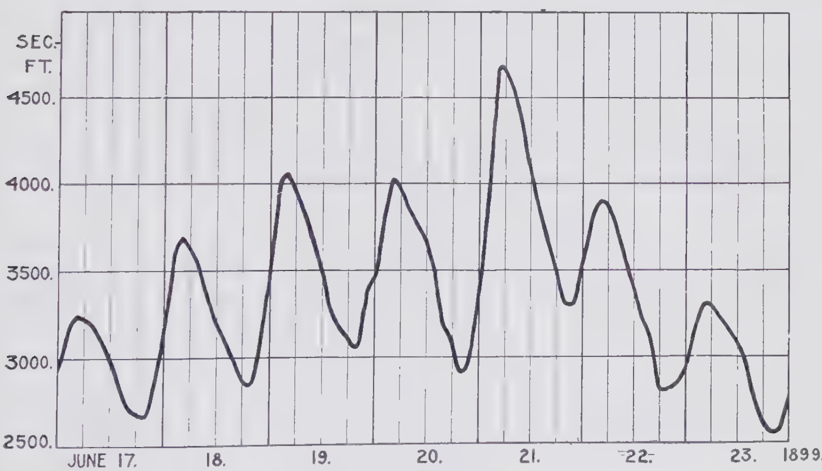

Figure 4.

which serves as a protection from the sun, whether forests, ridges, boulders or clouds, lessens the melting and tends to decrease these tides. This explains the paradoxical fact that a general rain in the mountains often lessens the amount of water in the river.

This effect is illustrated by Fig. 5, which shows the record of a rainy week in 1898. On June 1 the diurnal fluctuation was slight, on

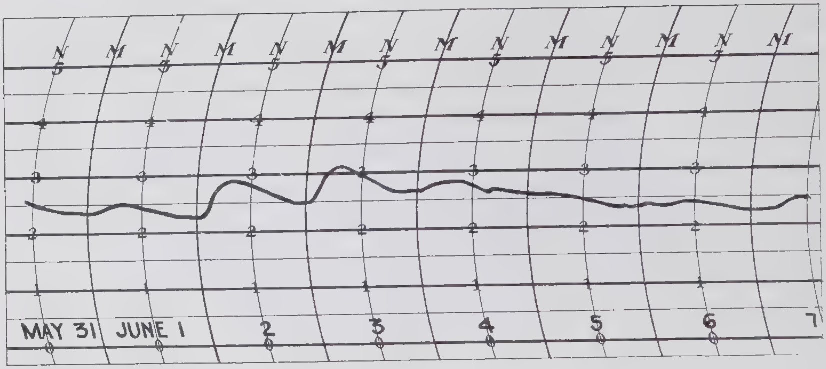

Figure 5.

June 2 it was more marked, and still more so on June 3. For the rest of the week it was scarcely noticeable. The days of June 1 and 2 were sunny, the two following days were rainy, and the rest of the week cloudy. On the night of June 3-4, 1.12 inches of rain fell at the Station, an unusually heavy rainfall, yet the river was lower after this rain than before. The clouds protected the snow from the sun, and this was of more effect than the exceptional rain.

Another record illustrating the effect of a general cloudiness, is for the last week in May, 1897, shown in Fig. 6. The flow for this week was

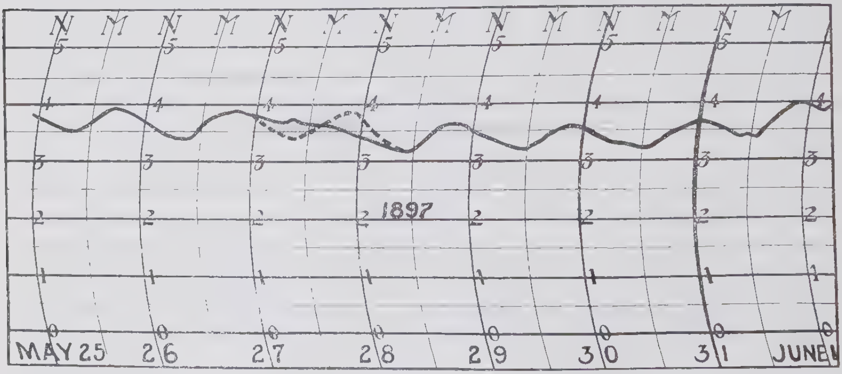

Figure 6.

normal, except on the 28th, when the river lacked the fluctuation evident on the other days. This was due to the character of June 27. It was cloudy and rainy all day at Fort Collins, and also over the whole watershed. The precipitation at the Station amounted to .28 in. There were hard showers near the river, as shown by the slight rise on the afternoon of the 27th. At Westlake, at an elevation of about 8,500 feet and about the middle of the watershed, the precipitation was .80 in. Notwithstanding this heavy rainfall the river shows a steady decrease. The dot-

ted line shows the probable course of the fluctuation, as judged from the records of co-operating observers, had there been no storm and the weather remained clear.

The different effect of a local shower on the river is shown in Fig. 7. Two local storms are in evidence on this record; one on the afternoon of May 18, and the other beginning to show on the afternoon of May 20, with a marked rise during the night.

The storm of May 18 was a sudden violent shower over a small area. As it was near the river, the effect was very marked. The rain-gauge at the Station recorded only .03 in. A shower of .20 in. on May 19 does not show; but there was a storm on the night of the 19th and extending throughout much of the forenoon of the 20th, amounting to 1.28 inches. This was heavy in the mountains also, especially at the lower elevations. The effect is seen in that the river continued to rise on the morning of the 20th, instead of falling. The sudden rise about midnight was due to the access of the flood from one of the important tributaries.

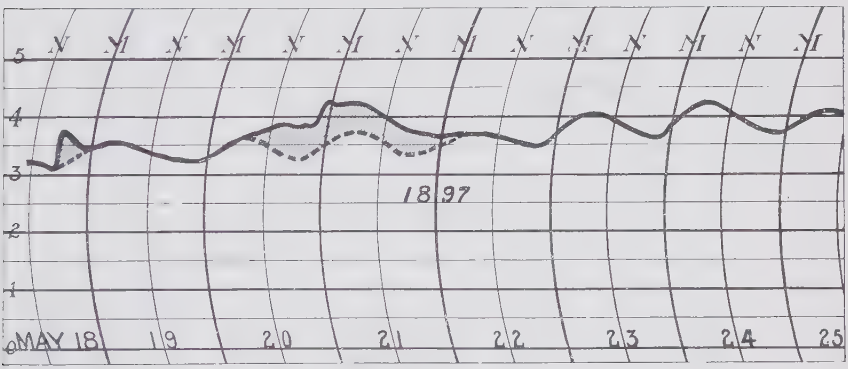

Figure 7.

The dotted line shows the probable fluctuation of the stream if there had been no storms. Neither of the storms extended to the higher elevations and did not cause general cloudiness, and the general course of the river was but little affected.

As snow is most evident on the high peaks, undue importance is attached to high elevations. The run-off from the forest fringes below timber line is of far more importance. The precipitation at the high elevations is not much, if any, more than at lower elevations. The rainfall on Pike's Peak, standing as it does on the edge of the Plains, cannot be considered representative of the other high elevations, and is undoubtedly much greater than that on other peaks equally as high. Even if a great amount of precipitation falls on the top, it is confined to a small area of relativey little importance. Thus, for instance, I have had occasion to examine the watershed tributary to the Rio Grande. While this has an area of 4,611 square miles above 8,000 feet elevation, there is less than 200 square miles of it above 12,000 feet, although this watershed has a large number of the highest peaks in the State.

In this case, over 90 per cent of the watershed is below timber line and above 8,000 feet.

That the forests in the mountains increase the amount of precipitation does not seem probable, whatever their effect when on the plains or lands of low elevation may be. The precipitation in the mountains is mostly due to the cooling from expansion, caused by the air being forced upward by the mountains. The effect of the forests would be so small compared with the mountains that it does not seem possible that they would increase the amount of rainfall. It, however, is not impossible that in the maintenance of moist conditions, influence on the currents of air, and the protection of slopes from the burning rays of the sun, there may be an effect even on the amount and distribution of the rainfall. Nevertheless, they influence the river floods, and protect the snows from melting and the action of the winds. As a protection from floods, they form a feature which the agricultural interests of the State should jealously protect.

CONCLUSIONS.

1. The mountain streams in the early irrigation season are largely supplied by melting snow.

2. There is a marked diurnal fluctuation, greater with high water than with low, due to the daily variation in the rate of melting.

3. The stream at high water may be one-half greater than at low water on the same day.

4. Cloudy weather in the mountains, protecting the snow from the radiation of the sun, causes the fluctuation to disappear and the flow to decrease.

5. This decrease is so great that the cloudiness associated with continued rain usually more than counterbalances the gain from the rain.

6. The loss of snow by evaporation is considerable, especially when exposed to winds.

7. Snow remains in the timber and in protected spots much longer than where exposed.

8. This is due not so much to drifting as to shelter from the radiation afforded by the forest cover.

9. Hence, the greater amount of forest cover the less violent the daily fluctuation, the more uniform the flow throughout the day and throughout the season, and the later the stream maintains its flow.

10. The loss of the forest cover means more violent fluctuation during the day, greater difficulty in regulating the headgates and keeping a uniform flow in ditches and hence an additional difficulty in the economic distribution of water. Also the water runs off sooner, hence the streams drop earlier in the summer and on account of the lessening of the springs, the smaller is the ~~water~~ flow. winter

11. The preservation of the forest is an absolute necessity for the interest of irrigated agriculture.

PLATES.

PLATE 1.—11:30 a. m., June 21, 1899. Elevation about 9,600 feet. Looking southwest into dead timber. Medicine Bow Range in the distance.

PLATE 2.—11:40 a. m., June 21, 1899. Looking northeast into open white pine timber. Ground sloping gently to the northwest. Snow drifts from three to five feet deep.

PLATE 3.—3 p. m., June 21, 1899. Looking east. Plates 9, 10, 11 and 12 were taken near here. Mr. Zimmerman is shown on the drift.

PLATE 4.—11:00 a. m., June 21, 1899. Looking northwest, showing Mr. Zimmerman behind drift. Slopes to the northwest. Drifts hard. Elevation about 9,600 feet. Open white pine timber. Nos. 5 and 6 taken from this point.

PLATE 5.—11:00 a. m., June 21, 1899. Looking north from same point as No. 4.

PLATE 6.—11:20 a. m., June 21, 1899. Looking southwest into dead timber.

PLATE 7.—10:30 a. m., June 21, 1899. Snow in the open white pine timber. Slopes to the north. Nearest drift, 60 feet long, 48 feet deep, 15 feet wide. Snow granulated. Elevation about 9,600 feet. Looking southwest.

PLATE 8.—4:05 p. m., June 19, 1899. Near No. 13. Snowdrift in the distant green timber.

PLATE 9.—12 m., June 21, 1899. Looking southwest. Bare slope. Elevation about 9,600 feet.

PLATE 10.—1:30 p. m., June 21, 1899. Drift 10 feet deep in green timber. Usually no snow here after June 1st. About 200 yards in timber from points where Plates 1 and 2 were taken.

PLATE 11.—2:45 p. m., June 21, 1899. Snow drift in green timber. From same point as Plate 12. Looking east. Ground slopes to east. Drifts about 12 feet deep, solid. Same drifts as in plates. Elevation about 9,000 feet. Four miles back of Zimmerman's.

PLATE 12.—2:40 p. m., June 21, 1899. From the same place as Plate 11. Looking southwest through dead timber. Mount Cameron in the distance.

PLATE 13.—8:50 a. m., June 24, 1899. Looking north. Elevation about 10,000 feet. Headwaters of the Laramie River. Ground slopes to the south.

PLATE 14.—9:45 a. m., June 24, 1899. Looking southwest. Near No. 13. Spruce and balsam.

PLATES 15, 16, 17 and 18.—June 24, 1899. From same point. Elevation about 9,800 feet. These views overlap, and may unite into one view. **No. 15,** 9:45 a. m. In dead timber, looking west. On south slope. **No. 16,** 10 a. m. Looking northwest into green timber. **No. 17,** 10:15 a. m. Looking north at south slope, showing snow in green timber. **No. 18.** 10:15 a. m. Looking northeast. Snow in green timber, bare ground in dead timber. Showing edge of snow between dead and green timber.

PLATE 1. From the same spot as Plate 2. Same date. Looking northwest.

PLATE 2. Looking northeast into green timber. June 21, 1899.

PLATE 3. Snow drift. June 21, 1899.

PLATE 4. From same point as Plates 5 and 6.

PLATE 5. On border between dead and green timber.

PLATE 6. Looking into dead timber.

PLATE 7. Snow-drifts in pine timber.

PLATE 8. Distant snow drifts.

PLATE 9. Looking southwest. Bare slopes.

PLATE 10. Drift in green timber.

PLATE 11. Looking east from same place as Plate 10.

PLATE 12. Looking southwest into dead timber.

PLATE 13. Snow in sheltered spots.

PLATE 14. **Snow in sheltered ravine.**

PLATE 15. Plates 16, 17 and 18 from same point. Looking west.

PLATE 16. Looking northwest.

PLATE 17. Snow in green timber looking north.

PLATE 18. Looking northeast.

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THE

BIRDS OF COLORADO

A *Second* Appendix to Bulletin No. 37

—BY—

W. W. COOKE

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FURTHER NOTES

ON

THE BIRDS OF COLORADO.

BY W. W. COOKE.

Since the publication in March, 1898, of the notes on Colorado birds that had been gathered the previous year, many additional notes have been secured. The largest number from any one source have come from a thorough study of the fine collection of Mr. Edwin Carter at Breckenridge. This collection represents the work of Mr. Carter for more than thirty years. Much of the material was gathered in the immediate vicinity of Breckenridge, and the rest in Middle Park and South Park. Breckenridge is at an altitude of 9,500 feet, while Middle and South Parks are from 7,500 to 8,500, so that Mr. Carter's collection is especially valuable as showing the bird life of the mountains and mountain parks. Breckenridge is on the western slope of the main range, and this collection furnishes several new records for the Pacific side of the mountains as well as a higher range than before known for more than thirty species. The Carter collection contains 184 species of birds, of which 127 are known to breed in Middle and South Parks. Mr. Carter has also taken 16 species that are not now in the collection. The collection adds two new birds to the state, *Ammodramus leconteii* and *Falco sparverius deserticolus*, and one new breeding record, *Wilsonia pusilla pileolata.*

Much space is given to notes from this collection, because the recent death of Mr. Carter makes the collection complete so far as his work is concerned. No catalogue or summary of this collection has ever been published. The present writer made three visits to Breckenridge, and has studied every bird in the collection at least twice. The last visit was but a few days before Mr. Carter left home on that last trip from which he was not to return alive. On this visit a complete investigation was made of all Mr. Carter's records of birds he had taken that are not now in

the collection. This bulletin therefore presents the full work of Mr. Carter with reference to Colorado ornithology. Many of the notes from his collection add nothing new to our knowledge of the birds of the state, but are entered in order to make a complete catalogue of the species represented in the collection.

Most of the rest of the new notes come from the further investigations of Mr. C. E. Aiken, who has spent a great deal of time the past two years in collecting and studying the birds of the "Divide" and the plains east of Colorado Springs. From his own collecting he has added five birds to the Colorado list, and of two more he has obtained the records from other persons. One of the excursions of Mr. Aiken deserves special mention as showing the possibilities of Colorado ornithology. The days from May 19-27, 1899, he spent in the vicinity of Limon, about a hundred miles out on the plains east of Colorado Springs. A poor place for birds one would think, and yet while there he encountered what seemed to be a flight of eastern birds that had wandered from their usual course and strayed several hundred miles to the westward, and mingled with them some distinctively western species scarcely to be expected east of the mountains. The Red-bellied Woodpecker, Tennessee Warbler, Least Flycatcher, Red-bellied Nuthatch, Bobolink and Scarlet Tanager were rare visitants from the east found there, and in addition he took the Connecticut Warbler and the Canadian Warbler, both being the first records for Colorado.

In contradistinction to this highly successful trip, may be noted one taken by the present writer, which also shows the peculiar distribution of bird life in Colorado. About the middle of May he went from Fort Collins to Grand Junction. The latter place is about a hundred and fifty miles further south and five hundred feet lower than Fort Collins. Vegetation was at least two weeks in advance of the more northern location, but bird migration was apparently in just the same stage; being another instance of what is probably a general rule, that migration on a western slope is later than on an eastern. More surprising than this, however, was the character of the birds seen. Grand Junction is three hundred miles west of Fort Collins, on the Pacific slope and on the Grand river, that one would expect to find a natural highway for birds from the west and south. The country was quite carefully explored for twenty miles along the Grand and Gunnison rivers, and in all somewhat over forty different species of birds were identified. They were all common birds of the eastern slope, occurring at Fort Collins, except the Raven and the California Quail. The former occurs over all of

western Colorado, while the latter has been introduced and has become exceedingly abundant. Out among the greasewoods, where greasewood is about the only vegetation that can grow, these Quail vie with the lizards as to which shall be the most common animal life present. In the whole trip not a distinctively southern or western species was observed, nor is there one in the list of sixty-one species of birds seen there by Miss Myra Eggleston during several years residence. The valley of the San Juan river serves as a great highway for southwestern forms into southwestern Colorado, and many extend along the Rio Grande into south central Colorado on the Atlantic slope, but apparently there is some conformation of land or condition of climate that keeps these forms away from west central Colorado.

The present bulletin is paged in continuation of bulletins Nos. 37 and 44, and references are to the pages of these bulletins. On page 3 the total number of species and varieties known to occur in Colorado should be changed to 387, of which 243 are known to breed. Thus in the three years since the Colorado list was published, 27 additions have been made and 15 more species ascertained to breed in the state. There is good reason to believe that the list, even now, is far from complete. A single fact will show how great are the future probabilities. In a small collection of beautifully mounted birds at Cheyenne, Wyoming, prepared by Mr. Frank Bond, are six species of birds taken by him at Cheyenne, less than ten miles from the Colorado line, that have not yet been found in this state. These species are *Sterna hirundo*, *Pelecanus fuscus*, *Crymophilus fulicarius*, *Ægialitis meloda circumcincta*, *Anthus spragueii* and *Cistothorus stellaris*, and there is every reason to believe that each of these will eventually be added to the Colorado list.

CLASSIFICATION OF COLORADO BIRDS.

Changes to be made, including those already made on page 128 and pages 148-150.

Page 8. **1. Residents:** Add

Callipepla squamata.
Tympanuchus americanus.
Phasianus torquatus.
Falco sparverius deserticolus.
Syrnium nebulosum.
Coccothraustes vespertinus montanus.

Page 9. **2. Winter visitants.** Omit

Coccothraustes vespertinus montanus.

Page 10. **4. Species that have been taken in Colorado in winter, either as rare or accidental visitors.** Add

Gavia arctica.
Larus philadelphia.
Somateria dresseri.
Nyctala tengmalmi richardsoni.
Acanthis linaria rostrata.
Junco montanus.

Page 11. *B. Species that breed on the plains, but only to the foothills of the mountains.* Add

Philohela minor.
Callipepla squamata.
Tympanuchus americanus.

Phasianus torquatus.
Syrnium nebulosum.
Phalænoptilus nuttallii nitidus.
Zamelodia ludoviciana.
Seiurus aurocapillus.
Harporhynchus bendirei.

Page 12. *C. Species that breed in the mountains or mountain parks and not on the plains.* Add

Falco sparverius deserticolus.
Coccothraustes vespertinus montanus.
Wilsonia pusilla pileolata.

D. Species that breed principally in the mountains. Add

Empidonax hammondi.

Page 13. *E. Species that breed regularly only in Southern Colorado.* Add

Plegadis guarauna.
Callipepla squamata.

Page 13. **6. Species taken in the State during the summer, but not known to breed.** Add

Gavia imber.
Aythya americana.
Charitonetta albeola.
Ardetta exilis.
Totanus flavipes.
Stellula calliope.
Astragalinus psaltria mexicanus.
Melospiza georgiana.

Omit

Plegadis guarauna.
Callipepla squamata.
Philohela minor.
Phalænoptilus nuttallii nitidus.
Seiurus aurocapillus.

Page 13. 7. **Migrants.** Add

Gavia adamsii.
Branta canadensis minima.
Porzana jamaicensis.
Astragalinus tristis pallidus.
Piranga erythromelas.
Dendroica palmarum.

Omit

Harporhynchus bendirei.

Page 14. 8. **Stragglers.** Add

Gavia adamsii.
Gavia arctica.
Somateria dresseri.
Branta canadensis minima.
Plegadis autumnalis.
Ardea egretta.
Porzana jamaicensis.
Nyctala tengmalmi richardsoni.
Bubo virginianus arcticus.
Coccyzus americanus.
Dryobates pubescens.
Stellula calliope.
Acanthis linaria rostrata.
Astragalinus psaltria mexicanus.
Ammodramus leconteii.
Melospiza georgiana.
Piranga erythromelas.
Dendroica palmarum.
Geothlypis agilis.
Geothlypis trichas.
Wilsonia canadensis.

Omit

Sylvania pusilla pileolata.
Harporhynchus bendirei.

Page 15. 10. **Rare or irregular visitants, from the east or southeast.** Add

Branta canadensis minima.
Plegadis autumnalis.

Ardea egretta.
Tympanuchus americanus.
Syrnium nebulosum.
Ammodramus leconteii.
Melospiza georgiana.
Zamelodia ludoviciana.
Piranga erythromelas.
Dendroica palmarum.
Geothlypis agilis.
Geothlypis trichas.
Wilsonia canadensis.

Page 16. **12. Rare or irregular visitants, from the west or southwest.** Add

Stellula calliope.
Astragalinus psaltria mexicanus.

Add the star (*) to denote breeding, to
Plegadis guarauna.

Page 16 **SUMMARY.**

Total species in Colorado	387
1. Residents	93
2. Regular winter visitants from the north	23
3. Regular breeders that sometimes occur in winter	17
4. Rare or accidental winter visitants	28
5. Summer residents	243
A. Breeding on plains and in mountains	101
B. Breeding on plains, but not in mountains	43
C. Breeding in mountains, but not on plains	56
D. Breeding principally in mountains, sparingly on plains	21
E. Breeding regularly only in southern Colorado	22
6. Summer visitants, not known to breed	18
7. Migrants	63
8. Stragglers	67
9. Regular visitants from east and southeast	14
10. Rare visitants from east and southeast	46
11. Regular visitants from west and southwest	20
12. Rare visitants from west and southwest	14

BIBLIOGRAPHY OF COLORADO ORNITHOLOGY.

Page 21. Add. AIKEN, C. E. *Otocoris alpestris arenicola. Colorado Springs Gazette* (local newspaper), Feb. 8, 1899.

Habits of this bird during cold weather.

Page 22. Add. ANTHONY, A. W. A new subspecies of the Genus Dryobates. *Auk, XIII.* 1896, *p. 32.*

Describes the subspecies *Dryobates villosus montanus.* Rocky Mountain Woodpecker with the type from Boulder, Colorado. In *Auk, XV.* 1898, *p. 54*, Anthony changes *montanus* to *monticola*, and as such this subspecies has been recognized by the A. O. U.

Page 22. Add. BAIRD, S. F. Smithsonian Miscellaneous Collections, 181, Review of American Birds in the Museum of the Smithsonian Institution. Part I. North and Middle America. Washington Smithsonian Institution, 1864-66, pp. IV., 450.

Contains incidental records of a few species of birds taken in Colorado.

BANGS, OUTRAM. A Review of the Three-toed Woodpeckers of North America. *Auk, XVII.* 1900, *p. 126.*

Description of *Picoides americanus dorsalis*, with notes on nine specimens taken in Colorado.

Page 26. Add. BREWSTER, WM. Lewis's Woodpecker Storing Acorns. *Auk, XV.* 1898, *p. 188.*

Habits of the birds as noted near Denver, Colorado, and reported to him by Manly Hardy.

Page 26. Add. CHRISTIE, N. R. The Pinon Jay. *Osprey, III.* 1898, *p. 57.*

Short account of its breeding habits near Rouse Junction, Colorado.

Page 27. Add. COOKE, W. W. The State Agricultural College, The Agricultural Experiment Station, Bulletin No. 44, Technical Series No. 4, Further Notes on the Birds of Colorado, An Appendix to Bulletin No. 37, on the Birds of Colorado. By W. W. Cooke. Approved by the Station Council, Alston Ellis, President. Fort Collins, Colorado, March,

1898. The Smith-Brooks Printing Company, Denver, *pp. 145-176.* [Date of distribution, March, 1898.]

Adds eleven new species to the state list; references to 15 books and articles; additional notes on 98 species.

COOKE, W. W. The Scarlet Ibis—A Correction. *Auk, XV.* 1898, *p. 183.*

Statement that the specimens of Scarlet Ibis reported in the *Auk, XIV.* 1897, *p. 316*, proved to be the White faced Glossy Ibis.

COOKE, W. W. A New Bird for Colorado. *Osprey, III.* 1898, *p. 13.*

A Le Conte's Sparrow taken by E. Carter at Breckenridge, October 2, 1886. It is stated that this is the first mountain record, but this is an error, as Merrill, *Auk, XV*, 1898, *p. 16*, had just previously recorded it from Idaho, west of the mountains, but at a much lower altitude. Breckenridge is 9,500 feet altitude. The article also contains records at Breckenridge of the Slate-colored Sparrow, Mockingbird and Bobolink.

COOKE, W. W. More New Birds for Colorado. *Auk, XVI.* 1899, *p. 187.*

Adds three new species to the state list, *Branta canadensis minima*, *Astragalinus psaltria mexicanus* and *Junco montanus.*

Page 29. Add. DILLE, F. M. Nesting of the Pine Siskin at Denver, Colo. *The Condor, II.* 1900, *p. 73.*

Several nests in the spring of 1899 within the city limits of Denver.

Page 31. Add. FREMONT, JOHN C. Report of the Exploring Expedition to the Rocky Mountains in the year 1842, and to Oregon and north California in the years 1843-4. By Brev. Capt. J. C. Fremont of the topographical engineers, under the orders of Col. J. J. Abert, chief of the topographical bureau. Printed by order of the House of Representatives, Washington; Blair & Rives, printers. 1845, *p. 586.*

Capt. Fremont crossed the State by way of the Grand river and the South Platte. His narrative contains only a few unimportant references to Colorado birds.

Page 31. Add. GILMORE, L. D. Western Goshawk in Colorado. *Osprey, III.* 1898, *p. 28.*

One shot at Sweetwater Lake, Garfield county, Colorado, February 12, 1898, by J. T. Meirer, and identified by the Smithsonian as *striatulus.* Two others seen later.

GILMORE, L. B. Some Notes on Colorado Birds. *Bul. Mich. Orn. Club. II.* April, 1898, *p. 19.*

Notes on seventeen species of birds seen in the vicinity of Dotsero, Colorado.

GILMORE, L. B. Notes on the Western Yellow-throat and Amer-

ican Raven in Colorado. *Bul. Mich. Orn. Club, III.* January, 1899, *p. 8.*

Notes on these two species seen near Dotsero.

Page 32. Add. HOWE, R. H., JR. Ranges of *Hylocichla fuscescens*, and *Hylocichla fuscescens salicicola* in North America. *Auk, XVII.* 1900, *p. 22.*

Measurements of two specimens of *salicicola* taken in Colorado.

Page 32. Add. INGERSOLL, EARNEST. Knocking Round the Rockies. Harper Bros., N. Y., 1883.

Contains descriptive notes on several Colorado birds.

Page 33. Add. "J." [CAPT. P. M. THORNE.] Snipe Wintering in Colorado. *Forest and Stream.* February 15, 1882.

Two Wilson's Snipe (*Gallinago delicata*) found February 3, 1882, at Fort Lyon, Colorado. The gizzard of the one shot contained partly digested fish.

Page 33. Add. JOHNSON, H. C. In the Breeding Home of Clarke's Nutcracker (*Nucifraga columbianus*). *The Condor, II.* 1900, *p. 49.*

Mentions all the nests of this bird taken in Colorado previous to 1900.

JONES, LYNDS. The Songs of the Warblers. (*Mniotiltidæ*). Laboratory Bulletin No. 10. Oberlin College. Also issued as Wilson Bulletin No. 30. Oberlin, Ohio, March 20, 1900, *p. 57.*

Notes on all the Warblers known to occur in the United States, with specific references to several of them as occurring in Colorado.

JONES, P. L. Flammulated Owls. *Osprey, III.* 1898, *p. 46.*

Records of three more captures near Beulah, Colorado, and one set of eggs.

Page 33. Add. KEYSER, LEANDER S. Rocky Mountain Birds. *Popular Science, XXXIV.* 1900, *p. 3.*

Short account of several common birds seen near Manitou.

KEYSER, LEANDER S. Rocky Mountain Birds. N. Y. Evening Post (newspaper), September 2, 1899.

Observations on the birds near Colorado Springs and Manitou.

Page 35. Add. NASH, H. W. Our Winter Birds. *The Cactus.* (Local magazine, Pueblo, Colorado.) *II, No. 1,* 1892.

Notes on the winter birds of Pueblo.

Page 35. Add. NELSON, E. W. Description of a new Subspecies of *Meleagris gallopavo* and proposed changes in the nomen-

clature of certain North American Birds. *Auk, XVII.* 1900, *p. 120.*

Describes a new sub-species, *Meleagris gallopavo merriami*, and assigns to it the wild turkeys of southwestern Colorado.

Page 35. Add. OBERHOLSER, HARRY C. Description of a new North American Thrush. *Auk, XV.* 1898, *p. 303.*

Describes *H. u. almæ*, subsp. nov. and gives Colorado as included in its habitat. This subspecies has been rejected by the A. O. U.

OBERHOLZER, HARRY C. A Revision of the Wrens of the Genus *Thryomanes* Sclater. *Proc. U. S. Nat. Mus., XXI. No. 1153,* 1898, *p. 427.*

Gives a new name, *Thryomanes bewickii eremophilus*, to the form that occurs in Colorado. Up to January, 1900, this had not been passed upon by the A. O. U.

Page 36. RIDGWAY, ROBERT. New Species, etc., of American Birds, II. Fringillidæ (continued). *Auk, XV.* 1898, *p. 319.*

Describes a new subspecies, *Calcarius lapponicus alascensis*, Alaskan Longspur, and includes Colorado in its habitat.

THE HISTORY OF COLORADO ORNITHOLOGY.

Page 41. Add.

1864-6. **Baird.** *Review of American Birds.* Adds *Lanius ludovicianus excubitorides* taken in Colorado by D. Thompson.

Page 42.

Under 1872. **Allen.** Omit *Lanius ludovicianus excubitorides*, as it had already been recorded by Baird in his Review of American Birds.

Page 48. Add.

1898. **Cooke.** *Osprey, III.* 1898, *p. 13.* *Ammodramus leconteii* taken by Carter at Breckenridge.

1899. **Cooke.** *Auk, XVI.* 1899, *p. 187.* *Astragalinus psaltria mexicanus* and *Branta canadensis minima* taken at Denver; *Junco montanus* taken at Pueblo.

1900. **Cooke.** *Colorado Experiment Station Bulletin No. 56.* The present publication contains the first records for Colorado of nine species as follows: *Gavia arctica, Ardetta egretta, Syrnium nebulosum, Astragalinus tristis pallidus, Geothlypis agilis, Geothlypis trichas* and *Wilsonia canadensis* by Aiken; *Plegadis autumnalis* by A. T. Allen; *Falco sparverius deserticolus* by Carter.

Page 48. **RECAPITULATION.** Add.

1898..	W. W. Cooke	1	364
1898..	W. W. Cooke	10	374
1898..	W. W. Cooke	1	375
1899..	W. W. Cooke	3	378
1900..	W. W. Cooke	9	387

THE BIRDS OF COLORADO.

Page 49. 1. **Æchmophorus occidentalis.** Western Grebe.

Two shot out of three seen on Sheldon's Lake, near Fort Collins, October 29, 1898, by Wils Black. One of them is now mounted in the museum of the Agricultural College.

This species has been seen by Edwin Carter in South Park, but not taken.

Page 49. 4. **Colymbus nigricollis californicus.** American Eared Grebe.

Has been seen at Breckenridge in migration by Edwin Carter, and breeds abundantly in Middle Park. In the following pages many records of Mr. Carter are given which are not in a certain sense new records, since they would be implied by the knowledge of the occurrence of the species in neighboring localities, but they are entered here both as a record of Mr. Carter's wide study of Colorado birds in localities not visited by other naturalists, and to furnish additional proof of the correctness of previous published records. Breckenridge is on the Blue River at an elevation of 9,500 feet, and about fifty miles from the junction of the Blue and the Grand rivers. Most of Mr. Carter's records of "Middle Park" meant the country around the mouth of the Blue river, with an altitude of 7,000–7,500 feet. His expeditions cover considerable of South Park, but most of his collecting has been along the branches of the South Platte on the eastern side of the park at about 8,000 feet.

Page 50. 6. **Podilymbus podiceps.** Pied-billed Grebe.

Seen by Mr. Carter at Breckenridge in migration, but never known to breed there.

Page 50. 7. Change to **Gavia imber.** Loon.

This and many changes given later are made to conform with the present nomenclature of the American Ornithologists'

Union. In the remainder of these notes the words "Change to" will be omitted and merely the present name given.

Seen by Mr. Carter in Middle Park. Mr. L. B. Gilmore reports that one was shot in July, 1897, on Sweetwater Lake, was mounted and is now in the possession of Mr. John Root. This is the first summer record for Colorado.

Page 50. Add. 9. **Gavia arctica.** BLACK-THROATED LOON.

A northern species occurring as a rare fall and winter visitant to Colorado.

Mr. C. E. Aiken of Colorado Springs, contributes the following notes.

"Three small Loons were observed on Prospect Lake in the suburbs of Colorado Springs, in November, 1898, and all were shot by a local gunner. One which I subsequently examined proved to be of this species.

"I also examined in 1883 a specimen killed, I think, the previous fall near Colorado Springs.

"Colorado is within the probable winter range of the species, and it may be a regular visitant."

Page 50. Add. [10. **Gavia pacifica.** PACIFIC LOON.

One was shot in November, 1899, near Clayton, New Mexico, just over the Colorado line, and was presented by Mr. Jesse Harris to the museum of the Agricultural College at Fort Collins.

This is the western form, not before recorded east of the Rocky Mountains.]

Page 50. Add. [11. **Gavia lumme.** RED-THROATED LOON.

The distribution of this species is given in the A. O. U. Check List as "Northern part of northern hemisphere, migrating southward in winter nearly across the United States." This would bring Colorado within the limits of its distribution, and hence it is one of the species that should be especially sought. It has been taken in Nebraska.

In the following pages about twenty such species are included as showing what will probably be found some day in Colorado, and to direct attention to them as species for future investigation.]

Page 50. 53. **Larus californicus.** CALIFORNIA GULL.

Mr. Carter's collection contains two specimens of this Gull; one taken April 28, 1884, in Middle Park at 7,000 feet, and the other taken at Denver, October 26, 1878.

Page 51. 54. **Larus delawarensis.** RING-BILLED GULL.

The present writer found this species breeding quite commonly June 18, 1898, at the San Luis Lakes at an altitude of 7,500, being more than a thousand feet above previous breeding records. Mr. Carter has never found them breeding nor seen them in fall migration, but in spring has seen them in both South and Middle Parks.

Page 51. 60. **Larus philadelphia.** BONAPARTE'S GULL.

Three more instances are known from Colorado Springs, Denver and Longmont. The one from Denver is in winter plumage. Mr. Carter has taken one in Middle Park in the spring, this being the first record for Colorado west of the range.

Page 51. 62. **Xema sabinii.** SABINE'S GULL.

Mr. Carter has a specimen taken September 26, 1886, on an alpine lake near Breckenridge at over 10,000 feet. Mr. Aiken killed one at Manitou Park, October 10, 1897.

Page 51. Add. [64. **Sterna tschegrava.** CASPIAN TERN.

"Nearly cosmopolitan: in North America breeding southward to Virginia, Lake Michigan, Texas, Nevada and California."—(A. O. U.) Has been taken in Nebraska and probably will later be added to Colorado birds.]

Page 51. 69. **Sterna forsteri.** FORSTER'S TERN.

Noted by Mr. Carter only in migration.

Page 51. Add. [70. **Sterna hirundo.** COMMON TERN.

This Tern occurs over all of North America, but chiefly east of the plains. Specimens of both young-of-the-year and old birds are in Mr. Bond's collection, taken at Cheyenne. It is also known from Kansas and Nebraska, so we may confidently expect that the future will add this to the list of Colorado birds.]

Page 52. [74. **Sterna antillarum.** LEAST TERN.

"Northern South America, northward to California, Minnesota and New England, and casually to Labrador, breeding nearly throughout its range."—(A. O. U.) Has been noted many times in both Nebraska and Kansas and undoubtedly comes into eastern Colorado, though up to the present it has no Colorado record.]

Page 52. Add. [121. **Phalacrocorax mexicanus.** MEXICAN CORMORANT.

"West Indies and Central America to southern United States; north in the interior to Kansas and southern Illinois."—(A. O. U.) There has also been a specimen reported from Nebraska, so it should be looked for in Colorado.]

Page 52. 125. **Pelecanus erythrorhynchos.** AMERICAN WHITE PELICAN.

Several late records indicate that these birds have not yet deserted Colorado. A flock of about forty was seen feeding on a small lake near Denver in the spring of 1898.

Mr. Carter has one taken at Breckenridge, August 10, 1892, has seen them in both Middle and South Parks, has seen them feeding on alpine lakes and even migrating over the mountain passes at 13,000 feet.

Page 52. Add. [126. **Pelecanus fuscus.** BROWN PELICAN.

One was taken July 12, 1899, near Cheyenne, Wyoming, and is now in the Bond collection.

Page 52. 129. **Merganser americanus.** American Merganser.

Breeds at Breckenridge.

Page 53. 130. **Merganser serrator.** Red-breasted Merganser.

One taken by Mr. Carter in Middle Park is the first record west of the range in Colorado.

Page 53. 131. **Lophodytes cucullatus.** Hooded Merganser.

Mr. Carter has one taken June 1, 1871, near Canon City.

Page 53. 132. **Anas boschas.** Mallard.

Taken breeding by Mr. Carter in South and Middle Parks.

Page 53. In place of 133. **Anas obscura.** Black Duck. Put 134a. **Anas fulvigula maculosa.** Mottled Duck.

Although no specimens of this duck taken in Colorado have been examined by the present writer, yet there can be no doubt that the three specimens reported really belong to this subspecies.

Page 53. 135. **Chaulelasmus streperus.** Gadwall.

Breeds in Middle Park, according to Mr. Carter.

Page 54. 137. **Mareca americana.** Baldpate.

Seen by Mr. Carter in summer in Middle Park at 7,000.

Page 54. 139. **Nettion carolinensis.** Green-winged Teal.

140. **Querquedula discors.** Blue-winged Teal.

141. **Querquedula cyanoptera.** Cinnamon Teal.

142. **Spatula clypeata.** Shoveller.

These four species of ducks have all been found by Mr. Carter at Breckenridge in migration, but are none of them known by him to breed at that altitude, though all breed in the great mountain parks.

Page 55. 143. **Dafila acuta.** Pintail.

Mr. Carter has taken Pintails in Middle Park at a little over 7,000 feet.

Page 55. 144. **Aix sponsa.** Wood Duck.

Two occurrences near Cheyenne are reported by Mr. Bond, who says they are quite common in northern Wyoming. Mr. A. T. Allen has known several instances in the vicinity of Denver, but none of these were in the summer.

Page 55. 146. **Aythya americana.** Redhead.

Facts are accumulating which make it probable that this species will in the near future be accounted among the breeding birds of Colorado. Several of these birds stayed in the reservoir at City Park in Denver all the summers of 1898 and 1899, but there was nothing to indicate that they nested there. A red-headed duck, presumably of this species, a fine male, was shot at the San Luis Lakes, June 18, 1898. This species, as well as the Canvas-back, is known to breed from northern United States northward.

Page 55. 147. **Aythya vallisneria.** Canvas-back.

Page 55. 148. **Aythya marila.** Scaup Duck.

Page 56. 149. **Aythya affinis.** Lesser Scaup Duck.

These three have been taken by Mr. Carter at Breckenridge in migration.

Page 56. 152. **Clangula islandica.** Barrow's Golden-eye.

Mr. Carter reports these ducks as common breeders in Middle Park, and that he once found them nesting at Georgia Pass at an altitude of 10,000 feet. As recorded by Brewer, *B. N. O. C. IV.*, 1879, *p. 148*, Mr. Carter took in Colorado in 1876 the first eggs of this species known to science.

Paae 56. 153. **Charitonetta albeola.** Buffle-head.

In the Carter collection is a fine male taken in Middle Park April 14, 1877, and a female taken May 5, 1884. Mr. Carter says that later in 1884, sometime in July, in Middle Park, he took both male and female. The male was in such worn plumage that it was not saved. The female was kept and mounted, but is not now on hand. Known to breed from northern United States northward.

Page 56. 154. **Harelda hyemalis.** Old-Squaw.

On October 16, 1898, B. Haywood killed two at Calkins' Lake near Longmont. On October 23 he killed another at the same place. Skins of two of these are now at the capitol at Denver.

Page 57. 155. **Histrionicus histrionicus.** Harlequin Duck.

Mr. Carter has found it breeding in Middle Park and on the Blue river a little below Breckenridge at 9,200 feet altitude.

Page 57. 165. **Oidemia deglandi.** White-winged Scoter.

One was shot on Barr Lake near Denver, November 2, 1898, and reported by Mr. Fenton.

Page 57. 166. **Oidemia perspicillata.** Surf Scoter.

Two were killed at Loveland on October 31, 1899, by Mr. H. A. Flynn of Denver.

A few days before, on October 22, Mr. L. B. Meek shot a fine male at Barr Lake near Denver. The female was with it, but was not secured. Three other specimens were known at the same place within the next week.

Page 57. 167. **Erismatura jamaicensis.** Ruddy Duck.

At Breckenridge, Mr. Carter knows them only as migrants, though they nest but a little lower down toward the Park.

Page 58. 169. **Chen hyperborea.** Lesser Snow Goose.

Once seen by Mr. Carter in Middle Park.

Page 58. 169a. **Chen hyperborea nivalis.** Greater Snow Goose.

One was killed by Mr. John F. Campion of Denver, at Boyd's Lake near Loveland, April 9, 1899. It was a female and is now in the capitol at Denver.

Page 58. Add. [169. 1. **Chen caerulescens.** Blue Goose.

"Interior of North America, breeding on eastern shores of Hudson Bay and migrating south, in winter, through Mississippi valley to Gulf coast." -(A. O. U.) "Interior of North America east of the Rocky Mountains."—(Goss.) Noted from Kansas and Nebraska as not uncommon in fall and winter.]

Page 58. 171a. **Anser albifrons gambeli.** American White-fronted Goose.

There is one in the Carter collection taken in Middle Park, and Mr. Carter says that in migration he has sometimes seen them there in quite large numbers.

Page 58. 172. **Branta canadensis.** Canada Goose.

In migration at Breckenridge and breeds in Middle Park.

Page 59. Add. 172c. **Branta canadensis minima.** Cackling Goose.

There is one at the capitol in Denver, killed by Mr. John F. Campion at Loveland, April 10, 1898, and presented by him to the State Natural History Society.

Page 59. 180. **Olor columbianus.** Whistling Swan.

One taken by Mr. Carter in Middle Park.

Page 60. Add. 186. **Plegadis autumnalis.** Glossy Ibis.

Accidental. A fine specimen of this bird in full plumage is

at Mr. A. T. Allen's in Denver. It was shot by him near Denver several years ago. This is the southern form and Denver is many miles north of its ordinary range. Mr. Aiken writes that Mr. B. G. Voight of Denver shot an adult male April 12, 1898, along the Arkansas river, three miles west of Salida. Mr. Voight has the mounted specimen still in his possession.

Page 60. 187. **Plegadis guarauna.** White-faced Glossy Ibis.

Several more records have been received. Two specimens were shot on Barr Lake near Denver, October 3, 1898. Four were shot in the fall at Twin Lakes at an elevation of 9,000 feet. Mr. A. T. Allen has a young-of-the-year taken near Denver. Mr. Carter has taken them in South and Middle Parks and at Twin Lakes, and there is a specimen at Glenwood Springs shot in the vicinity. These last two are the first records west of the range in Colorado.

Page 60. 188. **Tantalus loculator.** Wood Ibis.

Mr. Carter has seen the wing and bill of one taken on the Blue river, twenty-five miles below Breckenridge, at about 8,000 feet.

Page 60. 190. **Botaurus lentiginosus.** American Bittern.

Found by Mr. Carter breeding in both Middle and South Parks.

Noted by Mr. A. D. Baker in the Wet Mountain valley at 8,000 feet.

Page 61. 191. **Ardetta exilis.** Least Bittern.

A mounted specimen is now in Denver, taken by Mr. Rudolph Borcherdt on Berkeley Lake near Denver, June 8. 1898. Mr. Carter has one taken in South Park, May 14, 1875, and Mr. A. D. Baker has seen one in the Wet Mountain valley at over 8,000 feet.

Page 61. 194. **Ardea herodias.** Great Blue Heron.

Once found by Mr. Carter, breeding in Middle Park at 7,000 feet altitude, and it has been seen by Mr. A. D. Baker in the Wet Mountain valley at least a thousand feet higher.

Page 61. Add. 196. **Ardea egretta.** American Egret.

Rare or accidental in spring. Mr. C. E. Aiken writes as follows: "On May 12th, 1899, Mr. A. Gruber and Mr. F. Cikanck—taxidermists in my employ—reported seeing a single bird in a tall cottonwood tree five miles south of Colorado

Springs. As they are familiar with this species, as well as the more common *A. candidissima*, there appears no reason to doubt their identification.

Page 61. 197. **Ardea candidissima.** SNOWY HERON.

So many records for Colorado are accumulating of this species that it must be counted as a regular summer visitant to the state, whether or not it breeds. Two more specimens are known from Denver; three known by Mr. Aiken at Colorado Springs the spring of 1899; one at Glenwood Springs the spring of 1898, while Mr. Carter has not only taken them in Middle and South Parks, but even at Twin Lakes at 9,000 feet. A male and female were taken together by Mr. Carter, May 12, 1896, on the Gunnison river.

Page 61. Add. [201. **Ardea virescens.** GREEN HERON.

"Temperate North America."—(A. O. U.) Common summer resident of Nebraska and Kansas. Also known as common in the states west of Colorado. Should be noted before long from Colorado.

Page 61. 202. **Nycticorax nycticorax nævius.** BLACK-CROWNED NIGHT HERON.

In 1875 Mr. Aiken found them breeding at the San Luis Lakes and secured eggs. The present writer also found them there in 1898. Mr. Carter has taken them in both Middle and South Parks. Mr. L. B. Gilmore saw them on Sweetwater Lake at 8,000 feet, which is one of the highest records for this species.

Page 62. 205. **Grus canadensis.** LITTLE BROWN CRANE.

Mr. A. T. Allen has a mounted specimen, shot several years ago near Denver.

Page 62. 206. **Grus mexicana.** SANDHILL CRANE.

Mr. Carter has known of their breeding in Middle Park to about 8,000 feet, and Mr. Baker saw some November 15, 1899, in the Wet Mountain valley at about the same altitude.

Page 63. Add. [208. **Rallus elegans.** KING RAIL.

In Goss' "Birds of Kansas" this species is given as extending "West into Colorado." There seems to be an error about this, and there is at present no undoubted record of this bird in Colorado. Since, however, it is a common species in Kansas and Nebraska, nearly to the Colorado line, we may expect sooner or later to have the above record verified.]

Page 63. 212. **Rallus virginianus.** VIRGINIA RAIL.

Taken by Mr. Aiken at the San Luis Lakes, June 30, 1875, and therefore breeding there at 7,500 feet. One was brought to Mr. Aiken that was shot February 16, 1899, at a spring five miles from Colorado Springs. It was a male in good condition,

though this was the middle of one of the severest winters ever known in Colorado, with the temperature many degrees below zero. Several were said to have been seen, and also a smaller, darker kind that was probably *carolina*. Has been seen by Mr. Baker in the Wet Mountain valley at over 8,000 feet.

Page 63. 214. **Porzana carolina.** SORA.

Taken by Mr. Carter at Breckenridge, and breeds from Middle Park up the Blue river to about 9,000 feet.

Page 63. Add. [215. **Porzana noveboracensis.** YELLOW RAIL.

"Chiefly eastern North America, north to Nova Scotia, Hudson Bay, etc., less commonly west to Nevada and California."—(A. O. U.) Thus by implication Colorado is included in its habitat, but it has not yet been found here. Known as not uncommon in Kansas and Nebraska.]

Page 63. 221. **Fulica americana.** AMERICAN COOT.

Breeds in Middle and South Parks, but known by Mr. Carter at Breckenridge only in migration.

Page 63. 223. **Phalaropus lobatus.** NORTHERN PHALAROPE.

Mr. Carter saw several in Middle Park at 7,000 feet, May 26, 1884. He has taken them at Breckenridge in migration.

Page 63. 224. **Steganopus tricolor.** WILSON'S PHALAROPE.

Two pairs were taken near Glenwood Springs during the spring of 1898. Mr. Carter has taken them in migration in both Middle and South Parks, but not at Breckenridge. On September 1, 1885, he took a young-of-the-year at timber line.

Page 64. 225. **Recurvirostra americana.** AMERICAN AVOCET.

At the same places where Aiken found them breeding in the San Luis valley in 1875, the present writer found them breeding in 1898. Mr. Carter says that he has found them breeding in South Park, and has taken them in migration at Breckenridge.

Page 64. 230. **Gallinago delicata.** WILSON'S SNIPE.

Mr. L. B. Gilmore reports it as remaining nearly every winter around Sweetwater Lake at 8,000 feet. About January 20, 1900, he saw nine at one time. It also breeds sparingly in that vicinity. At Breckenridge it has been noted only in migration.

Page 65. 233. **Micropalama himantopus.** STILT SANDPIPER.

Several more records have come to hand of this rare Sandpiper. Mr. Aiken took one at Colorado Springs, May 14, 1884.

Mr. Carter has one taken at Breckenridge, and has also taken them years ago in both Middle and South Parks.

Page 65. Add. [234. **Tringa canutus.** KNOT.

"Nearly cosmopolitan. Breeds in high northern latitudes, but visits the southern hemisphere during its migrations."—(A. O. U.) Should be looked for in Colorado, as it has been taken in both Kansas and Nebraska.]

Page 65. 241. **Tringa bairdii.** BAIRD'S SANDPIPER.

242. **Tringa minutilla.** LEAST SANDPIPER.

246. **Ereunetes pusillus.** SEMIPALMATED SANDPIPER.

All three have been taken by Mr. Carter in Middle and South Parks.

Page 66. 249. **Limosa fedoa.** MARBLED GODWIT.

Mr. Carter has taken them as high as Breckenridge, far above their ordinary range.

Page 66. 254. **Totanus melanoleucus.** GREATER YELLOW-LEGS.

Taken by Mr. Carter in migration in both Middle and South Parks, and by Mr. Baker in Wet Mountain valley, at least to 8,000 feet.

Page 66. 255. **Totanus flavipes.** YELLOW-LEGS.

Taken by Mr. Carter in migration in both Middle and South Parks.

Page 67. 256. **Helodromas solitarius.** SOLITARY SANDPIPER.

Page 67. 258a. **Symphemia semipalmata inornata.** WESTERN WILLET.

At Breckenridge Mr. Carter has noted it only in migration.

Page 67. Add. [262. **Tryngites subruficollis.** BUFF-BREASTED SANDPIPER.

"North America, especially in the interior."—(A. O. U.) Known from Kansas and Nebraska and should be taken in Colorado.

Page 67. 263. **Actitis macularia.** SPOTTED SANDPIPER.

Breeds at Breckenridge.

Page 67. 264. **Numenius longirostris.** LONG-BILLED CURLEW.

Taken by Mr. Carter at Breckenridge in migration, and found by him breeding in Middle and South Parks.

Page 68. 270. **Squatarola squatarola.** BLACK-BELLIED PLOVER.

In Mr. Bond's collection is a very fine specimen in *full breeding plumage,* taken at Cheyenne, May 21, 1898.

Page 68. 273. **Ægialitis vocifera.** KILLDEER.
Breeds at Breckenridge.

Page 68. 274. **Ægialitis semipalmata.** SEMIPALMATED PLOVER.

One in Mr. Carter's collection was shot from a large flock seen by him in the fall on Grand Lake in Middle Park.

Page 68. Add. [277a. **Ægialitis meloda circumcincta.** BELTED PIPING PLOVER.

There is one in the Bond collection, taken at Cheyenne, May 13, 1892, but although this is so close to Colorado, and it is known in both Kansas and Nebraska, yet up to the present time it has no record for this State.]

Page 68. Add. [278. **Ægialitis nivosa.** SNOWY PLOVER.

"Western United States, from California east to Kansas and western Gulf States." –(A. O. U.) Surely this ought to include Colorado, but it has no record here as yet.]

Page 68. 281. **Ægialitis montana.** MOUNTAIN PLOVER.

Mr. Carter has never seen them at Breckenridge, even in migration, but has found them breeding in South Park.

Page 69. 283. **Arenaria interpres.** TURNSTONE.

Eight of these birds were killed on Berkeley Lake near Denver, May 18, 1900, and four of them, two males and two females, were mounted by Mr. Rudolph Borcherdt.

Page 69. 289. **Colinus virginianus.** BOB-WHITE.

Introduced about 1891 near Grand Junction and still occurs there, but not in anywhere near the numbers of the California Partridge. They occur in the Wet Mountain valley to at least 8,000 feet. They are native and not uncommon at Wray, in eastern Colorado on the plains.

Page 69. Add. [289b. **Colinus virginianus texanus.** TEXAN BOB-WHITE.

As its name implies, this is a Texas species, inhabitating southern and western Texas. It has been taken in southwestern Kansas. If it occurs anywhere in Colorado it would be in the extreme southeastern corner, along the Cimarron river. No ornithologist has ever penetrated this part of Colorado, which undoubtedly holds many new records for the fortunate one that explores it. It is fair to presume that of the dozen or fifteen species known to occur along the Cimarron a little further east, that have not yet been taken in Colorado, that several follow it up occasionally into this State. Whoever goes into that country should seek especially for the Lesser Prairie Hen, the Texan Bob-white, and settle definitely whether the Turkey of that region is the eastern form. So far as is known to the present writer, all of the Turkeys in the various collections in the State are referable to the Mexican form.

Page 69. 293. **Callipepla squamata.** SCALED PARTRIDGE.

A queer state of affairs has come to light in regard to the occurrence of this species in Colorado, that shows strongly how much there is yet to be learned about Colorado ornithology. In 1895 W. P. Lowe gave in the Auk the first published record of this species for Colorado. It was considered a rare specimen and extended the known range nearly three hundred miles north-eastward. Two years ago a specimen was sent to the present writer that was taken at Rocky Ford, but was supposed to have been introduced there. Now it has become known that they are common among the cedars on the higher arid lands back from the river and miles away from water. The cowboys that rode the range at least sixteen years ago, report that they were more plentiful there then than they are now. Lately they have been working toward the cultivated lands along the river, and during the winter of 1899-1900 they have become, in the vicinity of Rocky Ford, more common than the Bob-white. The Scaled Partridge should therefore be considered as resident; common locally.

Page 69. 294. **Lophortyx californicus.** CALIFORNIA PARTRIDGE.

A few years ago nearly a thousand of these birds were turned loose at Grand Junction. They have thriven wonderfully and the country now is full of them. They average two broods per year and the market gardeners claim they are a nuisance in their vegetable gardens.

Page 70. 295. **Lophortyx gambelii.** GAMBEL'S PARTRIDGE.

Page 70. 297. **Dendragapus obscurus.** DUSKY GROUSE.
Breeds at Breckenridge.

Page 70. 300b. **Bonasa umbellus umbelloides.** GRAY RUFFED GROUSE.

At last the present writer has had the good fortune to see this bird with his own eyes. A family of old and young were seen August 12, 1899, on South Fork in Estes Park, at 9,000 feet elevation.

Page 70. 304. **Lagopus leucurus.** WHITE-TAILED PTARMIGAN.
Breeds at Breckenridge.

Page 71. 305. **Tympanuchus americanus.** PRAIRIE HEN.

Resident. Further records of this species allow us now to include it among the breeders. Mr. Otto Derr writes that at

Wray the Prairie Hen is not an uncommon breeder, occurring there with the Sharp-tailed Grouse and Bob-white.

Page 71. 308b. **Pediœcetes phasianellus campestris.** PRAIRIE SHARP-TAILED GROUSE.

Mr. Carter says that they breed in Middle Park, but only in the lower parts, not above 7,500 feet. In winter they have been noted up to 9,500 feet.

Page 71. 309. **Centrocercus urophasianus.** SAGE GROUSE.

The highest that Mr. Carter has found them breeding is at Dillon, about 9,000 feet. In their migration, or more properly, wanderings, he has taken them at Breckenridge, and has even seen them crossing the main range at 14,000 feet.

Page 71. 310a. **Meleagris gallopavo fera.** WILD TURKEY.

As late as 1898 Turkeys were seen in Wet Mountain valley, and though they are entered here as belonging to the eastern form this is without sure proof, and the line in Colorado separating the two forms has not yet been settled.

Page 72. 310. **Meleagris gallopavo.** MEXICAN TURKEY.

The Turkey in Mr. Carter's collection is a well marked specimen of the western bird, though taken on the Atlantic slope in South Park in January, 1878.

Page 72. 312. **Columba fasciata.** BAND-TAILED PIGEON.

Mr. Carter has found them nesting in South Park, but has never seen them at Breckenridge. The present writer saw a flock of eight at Mary's Lake in Estes Park in August, 1898, and a single bird at the same place the next August.

Page 73. Add. [315. **Ectopistes migratorius.** PASSENGER PIGEON.

"Eastern North America, from Hudson Bay southward, and west to the Great Plains, straggling thence to Nevada and Washington."—(A. O. U.) It would be strange if the true eastern Pigeon did not occur occasionally in Colorado, and it has several times been reported here. All of these records or statements, when followed up, prove to be the Band-tailed Pigeon.]

Page 73. 316. **Zenaidura macroura.** MOURNING DOVE.

Breeds at Breckenridge.

Page 73. 319. **Melopelia leucoptera.** WHITE-WINGED DOVE.

One was shot by Mr. A. D. Baker in the Wet Mountain valley in September, 1899. This is the fourth record for Colorado, and makes it probable that the bird is not a mere straggler to the State.

Page 73. Add. [326. **Catharista urubu.** BLACK VULTURE.
"South Atlantic and Gulf States, * * * west to the Great Plains, * * * straggling north to South Dakota."—(A. O. U.) Has been taken in western Kansas and probably will some time be found as a rare summer visitant in southeastern Colorado.]

Page 73. 331. **Circus hudsonius.** MARSH HAWK.
Breeds to at least 8,000 feet, near Breckenridge.

Page 74. 332. **Accipiter velox.** SHARP-SHINNED HAWK.
Breeds at Breckenridge.

Page 74. 333. **Accipiter cooperi.** COOPER'S HAWK.
Not known by Mr. Carter to breed at Breckenridge, though not uncommon as a breeder a little lower in Middle Park.

Page 74. 334. **Accipiter atricapillus.** AMERICAN GOSHAWK.
Occurs at Breckenridge both in summer and in winter.

Page 74. 334a. **Accipiter atricapillus striatulus.** WESTERN GOSHAWK.
One was shot at Sweetwater Lake, Garfield county, February 12, 1898, by Mr. J. T. Meirer, and identified by the Smithsonian. Two others were seen later. One was taken near Colorado Springs in winter, and is now in Mr. Aiken's collection. Mr. Carter has quite a collection of Goshawks taken in the vicinity of Breckenridge, largely intermediates, but nearly half of them would be classed under the head of *striatulus.*

Page 75. 337b. **Buteo borealis calurus.** WESTERN RED-TAIL.
Page 75. 342. **Buteo swainsoni.** SWAINSON'S HAWK.
Page 75. 348. **Archibuteo ferrugineous.** FERRUGINOUS ROUGH-LEG.
Page 75. 349. **Aquila chrysaetos.** GOLDEN EAGLE.
These four are represented in the Carter collection and all breed at Breckenridge.

Page 76. 352. **Haliæetus leucocephalus.** BALD EAGLE.
Mr. Carter has known of its breeding at Breckenridge and nearly to 10,000 feet.

Page 76. 360. **Falco sparverius.** AMERICAN SPARROW HAWK.
A Sparrow Hawk in the collection of the Agricultural College at Fort Collins, taken on the plains near there, is referable to the eastern form, but shows a tendency toward the western. Of five adult birds in Mr. Carter's collection, taken in the moun-

tains, two are eastern and three western. One of the eastern birds was taken east of the range and the other west.

Page 76. Add. 360a. **Falco sparverius deserticolus.** DESERT SPARROW HAWK.

Resident. Two adult males and one adult female in Mr. Carter's collection are clearly referable to the western form. They were taken in Middle and South Parks.

Page 77. 364. **Pandion haliaetus carolinensis.** AMERICAN OSPREY.

Mr. Carter has seen them at Breckenridge, and knows of their nesting as high as 8,500 feet, on the Blue river.

Page 77. 365. **Strix pratincola.** AMERICAN BARN OWL.

One has been seen by Mr. A. D. Baker in the Wet Mountain valley. An adult female was shot at Rocky Ford in June, 1898, and is now in the collection of A. J. Dean.

Page 77. 366. **Asio wilsonianus.** AMERICAN LONG-EARED OWL.

Common near Breckenridge.

Page 77. 367. **Asio accipitrinus.** SHORT-EARED OWL.

Has been taken at Breckenridge in winter.

Page 77. Add. 368. **Syrnium nebulosum.** BARRED OWL.

Resident. A common species of eastern United States, west to Nebraska and Kansas, now first added to Colorado birds by the following note from Mr. C. E. Aiken:

"In March, 1897, Mr. B. G. Voight found a pair of these Owls breeding near Holyoke, in the northeast corner of the state. Two eggs, somewhat incubated, and one of the birds were secured."

Page 77. 371. **Nyctala tengmalmi richardsoni.** RICHARDSON'S OWL.

A second specimen for Colorado is the one taken by Mr. Carter at Breckenridge, December 28, 1882, and now in his collection.

Page 77. 372. **Nyctala acadica.** SAW-WHET OWL.

Mr. Carter's collection contains an adult taken at Breckenridge and also a young-of-the-year taken there August 10, 1884. Though Mr. Carter has seen no nests at Breckenridge, there can be little doubt that they breed there.

As the present writer was working on this part of this bulletin, January 31, 1900, one of our students caught a fine specimen in his hands in one of the evergreens near the main College building.

Page 78. 374. **Megascops flammeola.** FLAMMULATED SCREECH OWL.

Nine new records for Colorado and four instances of breeding can be added to the fourteen previous specimens known. P. L. Jones reports one found dead May 1, 1898; a female and two fresh eggs that proved infertile, June 27, 1898; a young male caught by a cat, September 12, 1898; a female and three eggs incubated about four days, June 5, 1899. All four cases were near Beulah, at less than 7,000 feet. Capt. D. B. Ingraham reports finding a female and two fresh eggs June 2, 1898, and two days later a female and two slightly incubated eggs, the latter within a hundred yards of where a female and three eggs were taken in 1897, near Beulah. Mr. C. E. Aiken reports two more specimens from Colorado Springs; one of these, taken on Fountain Creek, is the first summer specimen for the plains. There is one in the Carter collection, taken at Breckenridge, October 4, 1894. These make twenty-three records for Colorado and ten instances of nesting.

Page 80. 375b. **Bubo virginianus arcticus.** ARCTIC HORNED OWL.

Mr. Aiken reports a fine specimen killed near Colorado Springs, November 28, 1898. Another one said to have been seen. These notes of course refer to the lighter mountain form.

Up to the time of the issue of this bulletin, the A. O. U. has come to no conclusion in regard to what name shall be applied to this variety.

Horned Owls are common at Breckenridge, but in Mr. Carter's quite extensive series there are none of the lighter form.

Page 80. 376. **Nyctea nyctea.** SNOWY OWL.

Has been reported to Mr. Carter as taken near Breckenridge. The most southern record to date in Colorado is one known by Mr. Baker to have been seen in the Wet Mountain valley.

Page 81. 378. **Speotyto cunicularia hypogæa.** BURROWING OWL.

One in the Carter collection, taken in Middle Park.

Page 81. 379. **Glaucidium gnoma.** PYGMY OWL.

Mr. Carter reports it as breeding at Breckenridge.

Page 81. 385. **Geococcyx californianus.** Road-runner.

There is one in the Carter collection that was taken on the Arkansas above Canon City. Mr. Carter saw one several years ago near Littleton, which is the most northern record for the State.

Page 82. 387a. **Coccyzus americanus occidentalis.** California Cuckoo.

Taken by Mr. Carter in Middle Park.

Page 82. 390. **Ceryle alcyon.** Belted Kingfisher,

Mr. L. B. Gilmore records one that wintered in 1897-8 near the outlet of Sweetwater Lake, at about 8,000 feet.

Breeds at Breckenridge.

Page 82. 393e. **Dryobates villosus monticola.** Rocky Mountain Hairy Woodpecker.

This the present name given to the common form that occurs in Colorado. Breeds at Breckenridge.

Page 82. 394c. **Dryobates pubescens medianus.** Downy Woodpecker.

If the eastern form really occurs in Colorado, it would be of this subspecies.

Page 83. 394b. **Dryobates pubescens homorus.** Batchelder's Woodpecker.

Page 83. 401b. **Picoides americanus dorsalis.** Alpine Three-toed Woodpecker.

Page 83. 402a. **Sphyrapicus varius nuchalis.** Red-naped Sapsucker.

Page 84. 404. **Sphyrapicus thyroides.** Williamson's Sapsucker.

The last four species are all represented in Mr. Carter's collection, and have been taken by him as breeders at Breckenridge.

Page 84. 405a. **Ceophlœus pileatus abieticola.** Northern Pileated Woodpecker.

This becomes now the name of the Colorado bird.

Page 84. 406. **Melanerpes erythrocephalus.** Red headed Woodpecker.

Taken at Breckenridge by Mr. Carter, but not known to breed there.

Page 84. 408. **Melanerpes torquatus.** LEWIS'S WOODPECKER.

The statement of breeding for this species is a misprint. It should be: Breeds late in May. In calling attention to the error, Mr. Walter Blanchard of Boulder, writes that the earliest eggs he has known at Boulder were May 10, and the latest, June 14. Mr. Carter has seen the birds at Breckenridge, but does not know of their nesting there.

Page 84. 409. **Melanerpes carolinus.** RED-BELLIED WOODPECKER.

One was taken by Mr. C. E. Aiken near Limon in May, 1899.

Page 85. 412a. **Colaptes auratus luteus.** NORTHERN FLICKER.

It is probable that the Colorado bird should be referred to this form.

Page 85. 413. **Colaptes cafer.** RED SHAFTED FLICKER.

Breeds at Breckenridge.

Page 85. 418. **Phalænoptilus nuttallii.** POOR-WILL.

Mr. Carter reports their breeding in Middle Park.

Page 85. 420a. **Chordeiles virginianus henryi.** WESTERN NIGHTHAWK.

Page 86. 425. **Aeronautes melanoleucus.** WHITE-THROATED SWIFT.

Both these last two breed at Breckenridge.

Page 86. 429. **Trochilus alexandri.** BLACK-CHINNED HUMMINGBIRD.

Mr. Wm. Cross took a fine male at Glenwood Springs in 1898. This is the most northeasterly record to date.

Page 86. 432. **Selasphorus platycercus.** BROAD-TAILED HUMMINGBIRD.

Breeds at Breckenridge.

Page 86. 433. **Selasphorus rufus.** RUFOUS HUMMINGBIRD.

One was taken by Mr. Carter at Breckenridge, and it probably breeds there, though he has never found its nest.

Page 87. 436. **Stellula calliope.** CALLIOPE HUMMINGBIRD.

One of the most surprising specimens in Mr. Carter's collection is a fine Calliope Hummer taken near Breckenridge, June

30, 1882, at an altitude of about 9,500 feet. This is the second record for Colorado.

Page 87. 444. **Tyrannus tyrannus.** KINGBIRD.

Breeds in Middle Park, according to Mr. Carter.

Page 87. 447. **Tyrannus verticalis.** ARKANSAS KINGBIRD.

Mr. Carter has seen them at Breckenridge in migration, and knows of their breeding in Middle Park.

Page 87. 448. **Tyrannus vociferans.** CASSIN'S KINGBIRD.

Occurs in migration at Breckenridge and breeds only a little lower, nearly to 9,000 feet.

Page 87. 454. **Myiarchus cinerascens.** ASH-THROATED FLYCATCHER.

The known northeastern range of this bird has been considerably extended by a specimen in the Bond collection, taken at Cheyenne, Wyoming, June 6, 1896.

Page 88. 457. **Sayornis saya.** SAY'S PHŒBE.

Mr. Carter has taken it at Breckenridge, but does not know of its breeding there.

Page 88. 459. **Contopus borealis.** OLIVE SIDED FLYCATCHER.

Page 88. 462. **Contopus richardsonii.** WESTERN WOOD PEWEE.

Page 88. 464. **Empidonax difficilis.** WESTERN FLYCATCHER.

Page 88. 466. **Empidonax traillii.** TRAILL'S FLYCATCHER.

Of these four, the first three breed at Breckenridge, while the last occurs there in migration, but has not been noted breeding.

Page 89. 468. **Empidonax hammondi.** HAMMOND'S FLYCATCHER.

Known by Mr. Carter to breed as high as Dillon at 9,000 feet.

Page 89. 469. **Empidonax wrightii.** WRIGHT'S FLYCATCHER.

Occurs at Breckenridge in migration, but not known by Mr. Carter to breed there.

Page 89. 474c. **Otocoris alpestris arenicola.** DESERT HORNED LARK.

During February, 1899, Colorado experienced the most severe weather on record. Along the foothills from Fort Collins

to Colorado Springs the mercury fell to thirty below zero F. or lower. For two weeks or more, countless thousands of the Horned Larks flocked into the towns in search of food, and many thousands died of cold and hunger. Around the flour mills and elevators they came in clouds. Many persons made special provision for feeding them, one man giving them more than three thousand pounds of grain. Mr. Carter ascribes to this form the birds that breed at Breckenridge.

Page 89. 475. **Pica pica hudsonica.** AMERICAN MAGPIE.

Mr. Carter found them at Breckenridge breeding almost to timber line, at 10,500 feet.

Page 90. 478b. **Cyanocitta stelleri macrolopha.** LONG-CRESTED JAY.

At Boulder, Mr. Blanchard has taken the earliest sets of eggs May 11, 1896, May 15, 1897, and May 10, 1898.

Mr. Carter notes their breeding at Breckenridge.

Page 90. 484a. **Perisoreus canadensis capitalis.** ROCKY MOUNTAIN JAY.

Page 91. 486. **Corvus corax sinuatus.** AMERICAN RAVEN.

Both breed at Breckenridge.

Page 91. 487. **Corvus cryptoleucus.** WHITE-NECKED RAVEN.

There is one in the Carter collection, taken at Dillon in the fall of 1872. At that time they were quite common, Mr. Carter says, but have since disappeared.

One was seen by Mr. A. D. Baker in the Wet Mountain valley a few years ago. Mr. C. E. Aiken learned at Limon, out on the plains east of Colorado Springs, that one was seen there about ten years ago.

Page 92. 488. **Corvus americanus.** AMERICAN CROW.

Has been taken by Mr. Carter at Breckenridge, but is not known to breed there. Usually seen singly.

Page 92. 491. **Nucifraga columbiana.** CLARKE'S NUTCRACKER.

Breeds at Breckenridge.

Page 93. 492. **Cyanocephalus cyanocephalus.** PINON JAY.

Mr. Carter has seen them at Breckenridge in the fall, but during the summer season has not found them there or in either Middle or South Park.

Page 93. 494. **Dolichonyx oryzivorus.** BOBOLINK.

To the few records of this bird in Colorado Mr. Carter now adds two more. One was taken in Middle Park May 20, 1884, at 7,000 feet, and one taken in South Park May 21, 1876, at about 8,000 feet. These are farther west and at a higher altitude than any previous Colorado records. Mr. C. E. Aiken saw a female at Limon in May, 1899.

Page 93. 495. **Molothrus ater.** COWBIRD.

Page 93. 497. **Xanthocephalus xanthocephalus.** YELLOW-HEADED BLACKBIRD.

Page 94. 498. **Agelaius phœniceus.** RED-WINGED BLACKBIRD.

All three of these Blackbirds have been found by Mr. Carter breeding in Middle and South Parks, and all have been taken at Breckenridge, but only in migration.

Page 94. 501b. **Sturnella magna neglecta.** WESTERN MEADOWLARK.

Breeds at Breckenridge.

Page 95. 508. **Icterus bullocki.** BULLOCK'S ORIOLE.

Seen by Mr. Carter in Middle Park, but contrary to what would be expected, he has never seen it at Breckenridge.

Page 95. 510. **Scolecophagus cyanocephalus.** BREWER'S BLACKBIRD.

Breeds at Breckenridge.

Page 95. 514a. **Coccothraustes vespertinus montanus.** WESTERN EVENING GROSBEAK.

The record is now complete for Colorado for every month in the year. They had been seen in the State from the first week in August until late in May. On June 19, 1898, Mr. C. E. Aiken found a flock of twenty-five to thirty birds in the foothills near Colorado Springs. He killed five males. The testicles of each were the size of a bean, and it was evident that the birds were breeding in the mountains and had come down to feed on the insect larvæ that were ravaging the young oak leaves. The year is completed by the record of Mr. L. A. Test of the Agricultural College at Fort Collins, who on July 22, 1899, and again the next day, in Estes Park, saw a party of eight, apparently three old birds and five young ones. Mr. P. L. Jones of Beulah reports that during May and June, 1898, these birds were constantly around his premises. Late in June he saw a flock of seventeen,

composed of male and female and some birds which seemed to to be young-of-the-year, but were not captured for certain identification.

On the strength of these records this species will be classed as resident in Colorado.

Page 96. 515a. **Pinicola enucleator montana.** ROCKY MOUNTAIN PINE GROSBEAK.

Breeds at Breckenridge.

Page 96. 518. **Carpodacus cassini.** CASSIN'S PURPLE FINCH.

An abundant breeder at Breckenridge. Mr. Carter once found a male in immature plumage breeding with a mature female.

Page 97. 521a. **Loxia curvirostra stricklandi.** MEXICAN CROSSBILL.

A female or young-of-the-year male was seen by the present writer at Lamar, July 15, 1898. It seemed in perfect health and was probably an accidental wanderer who found himself here on the plains, one hundred and fifty miles east of the foothills. Breeds at Breckenridge.

Page 97. 524. **Leucosticte tephrocotis.** GRAY-CROWNED LEUCOSTICTE.

Page 98. 524a. **Leucosticte tephrocotis littoralis.** HEPBURN'S LEUCOSTICTE.

Page 98. 526. **Leucosticte australis.** BROWN-CAPPED LEUCOSTICTE.

Page 98. 528. **Acanthis linaria.** REDPOLL.

All four of these species have been taken in migration at Breckenridge by Mr. Carter, while the Brown-capped Leucosticte is an abundant breeder on the mountain tops above Breckenridge.

Page 98. 229. **Astragalinus tristis.** AMERICAN GOLDFINCH

Mr. Carter considers this a rare bird at Breckenridge, where he has seen it only in migration.

Page 99. Add. 529a. **Astragalinus tristis pallidus.** WESTERN GOLDFINCH.

Migratory; probably common. It is undoubtedly a summer resident, but until this fact is definitely ascertained it will be classed among the migrants according to the present record. Added to Colorado birds by Mr. C. E. Aiken, who writes:

"This paler Western Goldfinch occurs in Colorado as well as the typical eastern form to which all have heretofore been referred. I am not able at present to define their relative range or abundance with certainty. *Pallidus* is an early spring migrant along the eastern base of the mountains, and quite likely may be the alpine breeder. *Tristis* probably is a summer visitor from the southeast, occupying the plains to the base of the mountains. I have obtained both forms at Colorado Springs, and *tristis* one hundred miles eastward. Examples of both forms, which I recently sent to the American Museum of Natural History, have been kindly identified by Mr. Chapman with the concurrence of Dr. Allen."

Page 99. 530. **Astragalinus psaltria.** Arkansas Goldfinch.

Mr. Wm. Cross found this form breeding at Glenwood Springs during the summer of 1898. Mr. Aiken saw a very early flock at Colorado Springs May 13, 1898.

Page 99. 530a. **Astragalinus psaltria arizonæ.** Arizona Goldfinch.

Found by Mr. Wm. Cross breeding at Glenwood Springs during the summer of 1898. This is the most northwestern record in Colorado.

Page 99. Add. 530b. **Astragalinus psaltria mexicanus.** Mexican Goldfinch.

One taken by Mr. A. T. Allen in Denver and identified by Prof. J. A. Allen. There is also one in Mr. C. E. Aiken's collection taken near Colorado Springs. Near Trinidad, in June, 1898, the present writer is very sure that he saw two of them, though he failed to secure either of them. The species is entered as seen in summer but not known to breed. This is according to the present record, but it is with the belief that the species occurs at Trinidad as a regular summer resident.

Page 99. 533. **Spinus pinus.** Pine Siskin.

One of the few nests ever found on the plains is the one taken by Mr. F. M. Dille in the outskirts of Denver during the summer of 1898. Mr. Carter has taken it at Breckenridge.

Page 99. 000. **Passer domesticus.** European House Sparrow.

Miss Myra Eggleston reports that they reached Grand Junction during the fall of 1899, a flock of a dozen being seen. This is the first record for Colorado west of the range, and there

is nothing to indicate whether these birds reached Grand Junction from eastern Colorado or have come eastward from Utah. The distance is less from where they occur in Utah, and the mountain passes much lower.

Page 100. 534. **Passerina nivalis.** SNOWFLAKE.

Mr. Carter took one December 28, 1894, between Breckenridge and Middle Park at about 8,000 feet.

Page 100. 536a. **Calcarius lapponicus alascensis.** ALASKAN LONGSPUR.

This is the new name for the form of the Lapland Longspur that occurs in Colorado. It was seen but once by Mr. Carter at Breckenridge, where he took one, March 21, 1894, in the midst of a snowstorm. One nas been seen by Mr. Baker in the Wet Mountain valley at over 8,000 feet.

Page 101. 540a. **Poœcetes gramineus confinis.** WESTERN VESPER SPARROW.

Page 101. 542b. **Ammodramus sandwichensis alaudinus.** WESTERN SAVANNA SPARROW.

Both breed at Breckenridge.

Page 102. Add. 548. **Ammodramus leconteii.** LECONTE'S SPARROW.

The rarest find in the Carter collection is a specimen of this Sparrow, taken at Breckenridge October 24, 1886. This is the first record for Colorado, and its occurrence in the mountains three hundred miles west of its usual prairie home is of course accidental. This is the only record in the United States west of the main range, except the one noted by Merrill, *Auk, XV.* 1898, *p. 16*, taken in Idaho. Though Merrill's bird was reported first, Carter's was taken many years the earlier.

Page 102. 552a. **Chondestes grammacus strigatus.** WESTERN LARK SPARROW.

Breeds at Breckenridge.

Page 102. 553. **Zonotrichia querula.** HARRIS'S SPARROW.

The second record for Colorado of this bird is the one seen by the present writer at Holly, May 10, 1898. It was migrating in company with White-crowned Sparrows.

Page 102. 554. **Zonotrichia leucophrys.** WHITE-CROWNED SPARROW.

Breeds at Breckenridge.

Page 103. 559a. **Spizella monticola ochracea.** WESTERN TREE SPARROW.

Occurs at Breckenridge in migration.

Page 103. 560a. **Spizella socialis arizonæ.** WESTERN CHIPPING SPARROW.

Breeds at Breckenridge.

Page 104. Add. [563a. **Spizella pusilla arenacea.** WESTERN FIELD SPARROW.

"Great Plains, from Texas to Montana and Dakota."—(A. O. U.) A common summer resident of Kansas and Nebraska. Undoubtedly occurs on the plains of extreme eastern Colorado, but has not yet been reported.]

Page 104. 566. **Junco aikeni.** WHITE-WINGED JUNCO.

Page 105. 567b. **Junco hyemalis connectens.** SHUFELDT'S JUNCO.

Both taken at Breckenridge in migration.

Page 105. Add. 567.1. **Junco montanus.** MONTANA JUNCO.

This new form was recently described by Mr. Ridgway, who writes: "In our somewhat extensive series of *Junco montanus*, I find only one specimen from Colorado. This is a female, No. 109,943, U. S. N. M., collected at Pueblo, October 29, 1886, by C. W. Beckham. There are several examples from New Mexico and Arizona; all fall and winter birds." Mr. C. E. Aiken took this form at Ramah in February, 1899. He also has several specimens in his collection taken March 2, March 27 and October 25. The species therefore stands in the Colorado list as: Winter visitant, not uncommon; arrives the last of October and remains until late in March.

Page 105. 569. **Junco caniceps.** GRAY-HEADED JUNCO.

Breeds abundantly at Breckenridge, and in 1898 one nested under the eaves of Mr. Carter's house. A very late record for the plains was one taken by Mr. C. E. Aiken at Limon on May 25, 1899.

Page 106. 573a. **Amphispiza bilineata deserticola.** DESERT SPARROW.

This is the name now given to the bird that was formerly entered as the Black-throated Sparrow. Mr. P. L. Jones reports finding a nest with young near Canon City in 1888. This is the only time he saw the bird there in five years' residence.

Page 106. Add. [578. **Peucæa cassini.** CASSIN'S SPARROW.

"Central and western Kansas, southward and westward through Texas, New Mexico, Arizona and southern Nevada."—(A. O. U.) It would be difficult

to have any bird a rather common summer resident over the western half of Kansas, also common in New Mexico at the same season, and not have it occur in southeastern Colorado. But up to the present time no one has found it in this State.]

Page 107. 581b. **Melospiza fasciata montana.** MOUNTAIN SONG SPARROW.

Mr. Carter has taken it at Breckenridge only in migration. On the Blue river, at 7,500 feet, he took the nest and eggs July 5, 1877. He has never known it to nest above 8,000 feet.

Page 107. 583. **Melospiza lincolni.** LINCOLN'S SPARROW.

Breeds at Breckenridge.

Page 107. 585c. **Passerella iliaca schistacea.** SLATE-COLORED SPARROW.

A mounted specimen in Mr. Carter's collection was taken near the mouth of the Blue river in Grand county, July 5, 1877, at nearly 7,000 feet. This is one more summer record for Colorado, and the highest altitude at which it has yet been reported.

Page 108. 588a. **Pipilo maculatus megalonyx.** SPURRED TOWHEE.

Mr. Blanchard has found some eggs at Boulder as early as May 10. Mr. Carter has found it breeding nearly to Breckenridge.

Page 108. 592.1. **Oreospiza chlorura.** GREEN-TAILED TOWHEE.

This is the new number given to this species, hence it should come just after Abert's Towhee.

Mr. Carter has found it breeding as far up as Dillon, at 9,000 feet.

Page 108. 596. **Zamelodia melanocephala.** BLACK-HEADED GROSBEAK.

Found by Mr. Carter breeding in Middle Park and on the Blue river up to 8,500 feet.

Page 109. 597a. **Guiraca cærulea lazula.** WESTERN BLUE GROSBEAK.

Page 109. 598. **Cyanospiza cyanea.** INDIGO BUNTING.

Mr. Wm. Link saw several at Fort Collins about the middle of May, 1900. One was taken and is now mounted. They stayed round the premises for several days, and Mr. Link thought he saw three of them again in his yard May 30. This is the third record for Colorado.

Page 109. 599. **Cyanospiza amœna.** Lazuli Bunting.

Mr. Carter has not found it breeding higher than Middle Park.

Page 109. 604. **Spiza americana.** Dickcissel.

Mr. P. L. Jones of Beulah, reports finding the nest and eggs at Canon City in 1890. He saw the birds there during several years.

Page 109. 605. **Calamospiza melanocorys.** Lark Bunting.

Found by Mr. Carter breeding at Dillon at 9,000 feet.

Page 110. 607. **Piranga ludoviciana.** Louisiana Tanager.

Breeds at Breckenridge.

Page 110. 608. **Piranga erythromelas.** Scarlet Tanager.

One was reported to Mr. C. E. Aiken as seen at Limon in May, 1899.

Page 110. 611. **Progne subis.** Purple Martin.

Miss Myra Eggleston writes that Purple Martins are common at Grand Junction, but do not breed in town, preferring the banks of the river not far distant.

Page 110. 612. **Petrochelidon lunifrons.** Cliff Swallow.

Page 111. 613. **Hirundo erythrogaster.** Barn Swallow.

Page 111. 614. **Tachycineta bicolor.** Tree Swallow.

Page 111. 615. **Tachycineta thalassina.** Violet-green Swallow.

All these four breed in the mountains, though Mr. Carter has never seen the Tree Swallow breeding quite as high as Breckenridge, where the others are common.

Page 111. 618. **Ampelis garrulus.** Bohemian Waxwing.

Seen at Breckenridge in winter.

Page 112. 621. **Lanius borealis.** Northern Shrike.

Page 112. 622a. **Lanius ludovicianus excubitorides.** White-rumped Shrike.

Both of these have been taken by Mr. Carter, either at or near Breckenridge.

Page 112. 624. **Vireo olivaceus.** RED-EYED VIREO.

The Bond collection at Cheyenne, Wyoming, contains a specimen taken there May 26, 1889, and Rev. F. N. White saw one there May 20, 1899.

Page 112. 627. **Vireo gilvus.** WARBLING VIREO.

Page 112. 629b. **Vireo solitarius plumbeus.** PLUMBEOUS VIREO.

Both these species breed at Breckenridge.

Page 112. Add. [630. **Vireo atricapillus.** BLACK-CAPPED VIREO.

"Central and western Texas, from the Rio Grande north to southwestern Kansas."—(A. O. U.) Should be found along the Cimarron river in southeastern Colorado.]

Page 112. Add. [631. **Vireo noveboracensis.** WHITE-EYED VIREO.

"Eastern United States, west to the Rocky Mountains."—(A. O. U.) This should include Colorado, but there is no record known to the present writer from this State.]

Page 112. Add. [633. **Vireo bellii.** BELL'S VIREO.

"Upper Mississippi valley and Great Plains."—(A. O. U.) "From Illinois and Minnesota west to the eastern base of the Rocky Mountains."—(Goss.) "Inhabits the middle parts of the United States, from Illinois and Minnesota west to the foothills."—(Lantz.)

One would suppose from these statements that it was not uncommon in Colorado, and possibly it is not, but there is no record for it here up to the present time.]

Page 113. 644. **Helminthophila virginiæ.** VIRGINIA'S WARBLER.

Taken by Mr. Carter in both Middle and South Parks, where it breeds. Also taken by Mr. C. E. Aiken in May, 1899, at Limon, far out on the plains.

Page 113. 647. **Helminthophila peregrina.** TENNESSEE WARBLER.

There is one in the Bond collection, taken at Cheyenne, Wyoming, May 24, 1888.

One was taken by Mr. C. E. Aiken near Limon in May, 1899.

Page 114. 648. **Compsothlypis americana.** PARULA WARBLER.

The known northern range of this species is extended nearly two hundred miles by a specimen taken at Cheyenne, Wyoming, May 30, 1888, and now in the Bond collection.

Page 114. 652. **Dendroica æstira.** YELLOW WARBLER.

Breeds in Middle Park and at Breckenridge.

Page 115. 656. **Dendroica auduboni.** AUDUBON'S WARBLER.
Breeds at Breckenridge.

Page 115. 661. **Dendroica striata.** BLACK-POLL WARBLER.
There is a specimen taken by Mr. Bond at Cheyenne, Wyoming, May 11, 1888, and Rev. F. N. White saw one there May 15, 1899.

Page 116. 668. **Dendroica townsendi.** TOWNSEND'S WARBLER.

A young male was taken at Cheyenne, Wyoming, and is now in the Bond collection.

Page 116. 674. **Seiurus aurocapillus.** OVEN-BIRD.
On June 5, 1898, Mr. C. E. Aiken shot at Ramah a female with ovaries so extended that there seemed no doubt of its breeding. On the strength of this record the bird is included among the Colorado breeders.

Page 116. 675a. **Seiurus noveboracensis notabilis.** GRINNELL'S WATER-THRUSH.

One in the Bond collection at Cheyenne, Wyoming.

Page 116. Add. 678. **Geothlypis agilis.** CONNECTICUT WARBLER.

Migratory; rare or accidental. The first and only record for Colorado is the one taken by Mr. C. E. Aiken, who writes:

"On May 24, 1899, I shot a male in a clump of willows bordering a water hole at Lake, Lincoln county, about one hundred miles northeast of Colorado Springs. This unexpected capture adds an interesting eastern bird to the fauna of Colorado, and extends the known range of the species several hundred miles to the westward."

Page 116. 680. **Geothlypis tolmiei.** MACGILLIVRAY'S WARBLER.

Breeds in Middle Park, according to Mr. Carter.

Page 117. Add. 681. **Geothlypis trichas.** MARYLAND YELLOW-THROAT.

One taken by Mr. C. E. Aiken at Colorado Springs, May 31, 1898, and identified by Mr. Ridgway. This is the eastern form, rarely coming west to the plains.

Page 117. 681a. **Geothlypis trichas occidentalis.** WESTERN YELLOW-THROAT.

One was seen May 8, 1898, by Mr. L. B. Gilmore at Sweetwater Lake at 8,000 feet.

Mr. Carter has found it breeding at Dillon at 9,000 feet.

Page 117. 685. **Wilsonia pusilla.** WILSON'S WARBLER.

Page 117. 685a. **Wilsonia pusilla pileolata.** PILEOLATED WARBLER.

Its occurrence in Colorado will now be changed to: Summer resident; not uncommon.

There is in the Carter collection a specimen, quite typical, that was taken with nest and eggs at the eastern side of South Park, July 3, 1878. Mr. C. E. Aiken believes that this form is fully as common in Colorado as the eastern *pusilla*.

Page 118. Add. 686. **Wilsonia canadensis.** CANADIAN WARBLER.

Migratory; rare or accidental. Added to the Colorado list by Mr. C. E. Aiken in the following note:

"The range of this species is extended westward nearly to the Rocky Mountain range by my capture of a male at Lake, Lincoln county, May 23, 1899.

Page 118. 678. **Setophaga ruticilla.** AMERICAN REDSTART.

Breeds in Middle Park. The foregoing records show that of the twenty-nine Warblers known to occur in Colorado, but three have been taken breeding at Breckenridge by Mr. Carter, showing how few of these birds go up into the high mountains.

There are twenty-five Warblers given in the last edition of the A. O. U. Check List whose range is said to be "Eastern United States" or "Eastern United States to the Plains," thus not including Colorado in their habitat. These have all been taken in Kansas, and eleven of them have been found in Colorado. Since these eleven include several that would have been considered as little likely as any to be found in this State, we may expect that sooner or later most of the other fourteen will be noted in Colorado. Those not yet found here are *Protonotaria citrea, Helmitherus vermivorus, Helminthophila pinus, Helminthophila ruficapilla, Dendroica pensylvanica, Dendroica blackburniæ, Dendroica dominica albilora, Dendroica virens, Dendroica vigorsii, Dendroica discolor, Seiurus motacilla, Geothlypis formosa, Geothlypis philadelphia, and Wilsonia mitrata.*

Page 118. Add. [700. **Anthus spragueii.** SPRAGUE'S PIPIT.

It seems strange that there is no record of this bird for Colorado, when there are three specimens in the Bond collection, taken at Cheyenne, Wyoming, April 24, 1888, and it was undoubtedly seen there by Rev. F. N. White, April 29, 1899. It is unreasonable not to suppose that these birds crossed Colorado to reach Cheyenne. Moreover they are said to be: "Rare in eastern Kansas, common in the western part of the State."—(Lantz.) It is practically certain then that they occur in eastern Colorado, and that before long some one will find them there.]

Page 118. 701. **Cinclus mexicanus.** AMERICAN DIPPER.

Mr. Blanchard has taken nests on Boulder Creek four miles above Boulder at about 5,500. Two sets were taken, May 6 and May 12, 1898. All the sets he ever found in that locality were between May 1 and May 15. It is thus evident that these birds at the lower altitude nested earlier than is customary at the usual altitude.

Mr. Carter found the Dipper breeding at Breckenridge.

Page 119. 702. **Oroscoptes montanus.** SAGE THRASHER.

Mr. Carter has found them at Dillon at 9,000 feet, but does not know of their breeding higher than Middle Park.

Page 119. 703. **Mimus polyglottos.** MOCKINGBIRD.

The present writer saw two at the San Luis Lakes and one at La Jara on June 17 and 18, 1898. Mr. D. E. Newcomb of La Jara says that some years he sees them several times; other years they are absent. Miss Myra Eggleston reports them as breeding at Grand Junction. This completes the record for the whole southern half of Colorado, from Kansas to Utah.

There is one in the Carter collection, taken at Breckenridge August 12, 1891. This is 1,500 feet higher than any previous record, and was undoubtedly a wanderer.

Page 119. 704. **Galeoscoptes carolinensis.** CATBIRD.

The date of nesting should read the latter part of May, instead of June.

Mr. Carter reports it as a rare breeder in Middle Park.

Page 120. 715. **Salpinctes obsoletus.** ROCK WREN.

Breeds at Breckenridge.

Page 120. 719b. **Thryomanes bewickii leucogaster.** BAIRD'S WREN.

Page 120. 721b. **Troglodytes aedon aztecus.** WESTERN HOUSE WREN.

Breeds at Breckenridge.

Page 121. 722. **Anorthura hiemalis.** WINTER WREN.

One taken by Dr. W. H. Bergtold in Denver, July 8, 1896. This is the lowest summer record.

Page 121. Add. [724. **Cistothorus stellaris.** SHORT-BILLED MARSH WREN.

One in the Bond collection, taken at Cheyenne, Wyoming, April 14, 1889.]

Page 121. 725c. **Cistothorus palustris plesius.** WESTERN MARSH WREN.

Known by Mr. Carter to breed in South Park.

Page 121. 726b. **Certhia familiaris montana.** ROCKY MOUNTAIN CREEPER.

Page 122. 727a. **Sitta carolinensis aculeata.** SLENDER-BILLED NUTHATCH.

Page 122. 728. **Sitta canadensis.** RED-BREASTED NUTHATCH.

Page 122. 730. **Sitta pygmæa.** PYGMY NUTHATCH.

Page 122. 735a. **Parus atricapillus septentrionalis.** LONG-TAILED CHICKADEE.

Page 123. 738. **Parus gambeli.** MOUNTAIN CHICKADEE.

These last six species are all common birds of the mountains and have all been taken by Mr. Carter at Breckenridge. The present writer found the Mountain Chickadee common and evidently breeding at Trinidad, June 15, 1898. This is only 6,000 feet, much lower than this species usually nests.

Page 123. 744. **Psaltriparus plumbeus.** LEAD-COLORED BUSH-TIT.

During the summer of 1897 Capt. D. P. Ingraham took three sets of eggs near Beulah. Mr. C. E. Aiken has seen them occasionally in large flocks in winter in the foothills northeast of Canon City. He took a nest and five fresh eggs there May 9, 1876. Mr. Wm. Cross took the nest and six eggs at Glenwood Springs during the summer of 1898.

Page 123. 749. **Regulus calendula.** RUBY-CROWNED KINGLET.

A nest and seven eggs have been presented to the State Historical and Natural History Society of Denver, that were taken by Mr. Evan Lewis at Boswell, near Twin Lakes, June 12, 1898, at an elevation of 11,000 feet.

The lowest Mr. Carter has ever known of their nesting was at 7,000 feet, in Middle Park.

Page 124. 754. **Myadestes townsendii.** TOWNSEND'S SOLITAIRE.

Breeds above timber line near Breckenridge.

Page 124. 756a. **Hylocichla fuscescens salicicola.** WILLOW THRUSH.

Page 124. 758a. **Hylocichla ustulata swainsoni.** OLIVE-BACKED THRUSH.

Page 125. 759. **Hylocichla aonalaschkæ.** DWARF HERMIT THRUSH.

One taken by Mr. C. E. Aiken during the season of 1898, and three during the spring of 1899.

Page 125. 759a. **Hylocichla aonalaschkæ auduboni.** AUDUBON'S HERMIT THRUSH.

Breeds at Breckenridge.

Page 125. 759b. **Hylocichla aonalaschkæ pallasii.** HERMIT THRUSH.

Page 126. 761a. **Merula migratoria propinqua.** WESTERN ROBIN.

Breeds at Breckenridge.

Page 126. 766. **Sialia sialis.** BLUEBIRD.

Mr. Bond says that the Eastern Bluebird is a regular summer visitant to the City Park in Cheyenne, Wyoming.

Page 126. 767a. **Sialia mexicana bairdi.** CHESTNUT-BACKED BLUEBIRD.

Mr. Carter has found it breeding in South Park, but never as high as Breckenridge.

Page 126. 768. **Sialia arctica.** MOUNTAIN BLUEBIRD.

Breeds at Breckenridge.

Page 148. *B. Species that breed on the plains.* Omit

Helminthophila peregrina.

Page 149. 7. **Migrants.** Omit

Helminthophila peregrina.

Page 155. 8. **Gavia adamsii.** YELLOW-BILLED LOON.

Page 156. 160. **Somateria dresseri.** American Eider.

Further research has shown that the specimen mentioned at the capitol at Denver was taken outside of Colorado.

Page 162. 418a. **Phalænoptilus nuttallii nitidus.** Frosted Poor-will.

The two specimens taken by Mr. Aiken have been later identified as true *nuttallii*.

Page 167. 595. **Zamelodia ludoviciana.** Rose-breasted Grosbeak.

Page 168. 647. **Helminthophila peregrina.** Tennessee Warbler.

This is now withdrawn from the list of Colorado breeders since Mr. Aiken has satisfied himself that the record is a misidentification for Virginia's Warbler.

ADDENDUM.

While the last pages of this bulletin are passing through the press, the *Auk* for July, 1900, is received, necessitating the following addition:

Page 186. Add. Aiken, C. E. Seven New Birds for Colorado. *Auk, XVII.* 1900, *p. 298.*

Adds to the Colorado list, *Gavia arctica, Ardea egretta, Syrnium nebulosum, Astragalinus tristis pallidus, Geothlypis agilis, Geothlypis trichas, Wilsonia canadensis.*

The records of these birds for Colorado have been given in this bulletin, but since the article in the *Auk* was published first, it becomes the first record of these birds for Colorado, instead of this bulletin.

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FARM NOTES.

By W. W. COOKE.

The following bulletin contains the records of various tests that have been made on the college farm during the years 1894 to 1899. They are grouped under the following headings:

I. Alfalfa.

a—Losses in cutting and curing.
b—Losses in the stack and in the barn.
c—Alfalfa ensilage..
d—Three methods of handling alfalfa.
e—Top-dressing alfalfa.
f—Moisture in green alfalfa.
g—Moisture in alfalfa hay.

II. Corn.

a—Silo notes.
b—Seed corn from different altitudes and latitudes.
c—Variety tests of corn.
d—Number of stalks in a hill.
e—Missing hills in a corn field.

III. Potatoes.

a—Alfalfa sod compared with old land.
b—Experiments with fertilizers.

IV. Sugar Beets.

a—Subsoiling for sugar beets.
b—Sugar beets in Colorado in 1899.
1. Time of planting.
2. Distance between rows.
3. Irrigating the seed.
4. Variety tests.
5. Summary.

I. ALFALFA.

A—LOSSES IN CUTTING AND CURING.

It has long been known that there was some loss in making alfalfa hay. Part of this loss is chemical, arising from the fermentation of the hay when exposed to rains during the curing process. The rest of the loss is mechanical and consists of the breaking off of the leaves and smaller ends of the branches when the alfalfa is hauled after it becomes dry. To overcome the latter loss, so far as possible, it is customary to rake the alfalfa while it is yet far from dry, and, particularly, early in the morning while the dew still makes it damp and pliable. It is also cocked while still quite moist, and allowed to dry out slowly. Both these methods, while saving the mechanical losses, tend toward the increasing of the chemical losses through fermentation.

To ascertain the exact amount of these losses several experiments have been made in different years.

In the first set of tests, the field was divided into several long narrow strips. The whole field was cut at the same time, then every other strip was gathered up at once, weighed and three samples taken. The alternate plots were made into hay according to our usual methods. When fully cured this hay was brought to the barn, weighed and four samples taken. The weight of the first multiplied by the average composition of the samples gives the value of the alfalfa when cut; the weight of the hay when cured, multiplied by its average composition gives its value after curing. The supposition was made that the alfalfa left on the ground weighed the same and had the same composition as that gathered up. Since the number of plots was never less than ten and the size was quite large, it is probable that the error, if any, was quite small.

Three tests were made in this manner, and they illustrate the different conditions under which alfalfa hay is cured.

The first cutting was made May 28 and owing to several rains and considerable cloudy weather, it was not until June 12 that the hay was ready to go into the barn. This hay

had a hard time of it, but no worse than often happens to the first cutting of alfalfa in northern Colorado. The plots gathered up at once on May 28 yielded at the rate of 16,553 pounds of green alfalfa per acre, which contained 23.2 per cent of dry matter or 3,840 pounds of dry matter per acre. After the fifteen days of hardship the final hay secured weighed 3,302 pounds per acre, with 86.0 per cent of dry matter or 2,839 pounds of dry matter per acre. Thus, of the original 3,840 pounds of dry matter, but 2,839 pounds were saved, showing a loss of 1,001 pounds per acre or 26.1 per cent.

In the second test the alfalfa was cut June 21, raked and cocked June 23, and brought to the barn June 28, or seven days after cutting. The only moisture on this hay was a small rain and a mere sprinkle, both coming after the hay was in the cock, and neither enough so that the hay had to be opened up to dry. This case represents the ordinary good conditions of the first crop of alfalfa in Colorado. At the time of cutting the field yielded at the rate of 16,258 pounds of alfalfa per acre, containing 30.3 of dry matter or 4,926 pounds of dry matter per acre. The hay put in the barn weighed 4,900 pounds per acre and was very dry, testing 90.3 per cent dry matter or 4,425 pounds of dry matter per acre. In this case, of the original 4,926 pounds of dry matter, 4,425 pounds were saved; a loss of 501 pounds per acre or a loss of 10. 2 per cent.

The third trial was made in September, under perfect weather conditions, the hay coming to the barn without having had a drop of moisture fall on it. The crop was the heaviest ever cut on the College farm in the fall. The green weight was 13,133 pounds per acre, containing 38.0 per cent dry matter, or 4,990 pounds dry matter per acre. This field produced, in the whole season, a little over seven and a half tons of hay per acre. When the experimental hay was put in the stack it weighed 5,097 pounds per acre and contained 93.0 per cent dry matter or 4,740 pounds of dry matter per acre. So, in this third trial there was a loss of but 5.1 per cent of the value of the hay in curing and stacking.

The other method used for making a test of this same point was to cut the field and at once gather up the alfalfa from sixteen different plots scattered over the field, each plot being twenty feet long and the width of the mower swath. It was considered that these sixteen plots of over a thousand square feet would represent the average of the field.

In the first test the alfalfa was cut June 8, raked June 12, cocked the 14th and taken to the barn June 16. The

weather on June 9 and 10 was cloudy with some showers, but at this time the alfalfa had not yet dried much and it was but little injured by the rain. It showed a total loss of 9.0 per cent of value in the curing and gathering.

The next sample was cut June 15, raked June 17, cocked June 18 and gotten in the same day; all without a drop of rain. It also showed 9.0 per cent loss.

The third lot was cut June 22, raked and cocked June 24. That night a quarter of an inch of rain fell and the next day was showery. The hay was opened up, turned and recocked June 26 and taken to the barn June 28. It showed a loss of 13.0 per cent of dry matter.

Another field was cut June 15, raked June 18, cocked June 19 and gotten in June 22. The weather was perfect and the hay showed 11.0 per cent of loss. Still another field cut at about the same time and under the best of conditions, showed 10.0 per cent loss.

We thus have eight tests of the losses in curing and gathering alfalfa. They vary from 5.1 per cent to 26.1 per cent, with an average of 11.7 per cent.

It is probable that this average is not far from the real average of the losses on the alfalfa in Colorado that does not suffer any hard rain. The first test with a loss of 26.1 per cent, shows what may easily happen under bad conditions.

It is specially to be noted that the hay which was made in perfect weather shows about the same loss as that which had cloudy weather and light showers. The hay that dried most rapidly became so brittle that the mechanical losses of leaves and stem were fully equal to the losses by fermentation during the damper weather.

B—LOSSES OF ALFALFA IN THE STACK AND IN THE BARN.

A test was made to determine how much of its feeding value was lost by alfalfa hay after it was put in the stack and how much of that loss could be saved by putting the hay in a barn.

A field of alfalfa was all cut the same day, handled alike until made into well cured hay, then it was hauled and each two loads put alternately in the stack and in the barn. The stack was divided by slats into four layers and the hay in the barn into four corresponding layers. The hay in each layer was weighed separately and duplicate samples taken for analysis. This hay was the first cutting and was put in the stack June 15. It remained in the stack eight months and on

February 16 all the layers of the stack and in the barn were again weighed and sampled. The stack was about the same height and width of the usual alfalfa stack in Colorado and its being shorter than the average scarcely affects the results.

As would be expected the top and bottom layers of the stack suffer more loss than the middle layers. The top layer lost about five per cent of its weight in spoiled hay and the bottom layer about the same per cent of waste hay that was so injured by the dampness of the ground as to be unsalable.

All the layers lost considerably in weight as follows:

LOSS OF WEIGHT IN STACK.

Layer.	Weight as put in June 15.	Weight when taken out Feb. 12.	Per cent of loss in weight.
Bottom	5048	4160	17.6
Second	4906	4244	13.5
Third	4754	3946	17.0
Top	4664	3554	23 8
Average	4843	3986	17.7

This loss, however, is largely due to the drying out of the water in the hay. As put up the hay averaged 18.9 per cent of water; as taken out this had dried to but 11.1 per cent of water. The changes that took place in the dry matter give these figures:

LOSS OF DRY MATTER IN STACK.

Layer.	Dry Matter as put in June 15.	Dry matter when taken out Feb. 12.	Per cent of loss in dry matter.
Bottom	4069	3593	11.7
Second	4031	3818	5.3
Third	4030	3550	11.9
Top	3585	3197	10.8
Average	3929	3539	10.0

This latter table does not show the loss in real feeding value, for both the top and the bottom layers had some hay that could not be used for feeding. If the amount of this spoiled hay is subtracted, it leaves the following as the losses of feeding value:

LOSS OF FEEDING VALUE IN STACK.

Layer.	Feeding value as put in June 15.	Feeding value when taken out Feb. 12.	Per cent of loss in feeding value.
Bottom	4069	3390	16 8
Second	4031	3818	5.3
Third	4030	3550	11 9
Top	3585	2997	16 1
Average	3929	3439	12.4

The results show that for every hundred pounds of hay

put into the stack 82.3 pounds were taken out and for every hundred pounds of feeding value in the hay as put in the stack 12.4 pounds were lost and 87.6 pounds were saved. The loss is one-eighth; that is, for every eight tons of feeding value in the original hay, seven tons are saved and one lost.

Chemical analyses were made of the hay as put into the middle layers of the stack and as taken out. A comparison of the two analyses shows what changes took place in the hay during process of curing in the stack.

COMPOSITION OF THE STACKED HAY.

	As put in June 15.	As taken out February 12.
Water	16.6	10.0
Dry Matter	83.4	90.0
Analysis of Dry Matter—		
Ash	9.91	11.84
Ether Extract	1.25	1.34
Crude Protein	15.07	14.74
Crude Fiber	36.97	38.62
Nitrogen-free Extract	36.79	33.46

The analysis taken in connection with the weights shows that the following losses of food ingredients took place in these middle layers of the stack.

LOSS OF FOOD INGREDIENTS IN THE STACK.

	As put in June 15.	As taken out February 12.	Per cent of loss.
Ether Extract	101	99	2.0
Crude Protein	1214	1086	10.5
Crude Fiber	2978	2845	4.4
Nitrogen-free Extract	2964	2465	16.8
Total	7257	6495	10.5

Samples were also taken and analyzed of the load from the top of the stack and from the bottom. The analyses are given below in comparison with the composition of the alfalfa when put in the stack.

	Original.	Top of stack.	Bottom of stack
Ash	9.91	11.64	12.18
Ether Extract	1 25	1.47	1.77
Crude Protein	15.07	15.94	17.04
Crude Fiber	36.97	38.82	36.84
Nitrogen-free Extract	36.79	32.13	32.75

In the top of the stack the loss falls on both the protein and the extract matter, while at the bottom the loss is almost confined to the extract matter and crude fiber. In both cases the loss of carbohydrates is greater than in the middle layers.

The losses on the hay that was put in the barn show quite a different result:

LOSS OF WEIGHT IN BARN.

Layer	Weight as put in June 15.	Weight when taken out February 12.	Per cent of loss in weight.
Bottom	3778	3480	7.9
Second	4752	4091	13.8
Third	4696	4103	12.6
Top	4236	3663	13.5
Average	4365	3834	12.2

Judging by these figures alone one would think that the losses in the barn had been nearly as much as in the stack. A study of the amounts of dry matter shows that these losses are almost entirely losses in weight of water. The hay as put in the barn contained 20.8 per cent of water; when taken out it contained but 12.1 per cent of water. There were 13,804 pounds of dry matter put into the barn and 13,478 pounds of dry matter taken out, being a loss of but 2.5 per cent. Since there was no waste hay this 2.5 per cent represents also the loss in feeding value in the barn.

The final averages show 12.4 per cent of feeding value lost in the stack, while but 2.5 per cent of feeding value was lost from the hay that was put in the barn. This shows a difference of ten per cent in favor of the barn.

In other words *nine tons of hay put in the barn will feed as much stock as ten tons put in the stack.*

It should be remembered that while these results indicate average conditions for the barn, they represent rather better than average figures for stacks of the first cutting of alfalfa in Northern Colorado. The stack under experiment was put up in good shape and had a chance to settle well before much rain fell upon it, while the season was in general favorable for hay in stack. These figures may be said to represent the least losses that one should expect with the first cutting. Had the same test been made in 1895 a very different story would result. That year at least one-third of the dry matter in the stack was lost. We made an extended test of the feeding value of this injured stack hay as compared with similar hay from the barn. It was found that the sheep eating the two lots of hay made exactly the same gain for the entire five months of the test, but for every two tons of hay from the barn we had to draw three tons from the stack, and this was in addition to the large amounts of worthless hay on the tops and bottoms of the stack. In that year therefore 4.4 tons of hay put into the barn yielded as much feed as 10 tons in the stack.

Of course this is an extreme case, but the average loss of all years for Northern Colorado is probably not less than a

fifth, that is, eight tons of hay in the barn is equal to ten tons of hay in the stack.

It may be asked why the farmers do not build barns for their hay and save these large losses. The answer is easily given. Barns are expensive to build and keep in repair; the labor of putting hay into the barn and feeding it to any stock, except milch cows, is considerably more than to handle the hay by stacking. At present low prices of hay, the two items above more than equal the losses of hay in the stack. It seems probable that at six dollars a ton the gains will about equal the losses, and at above that price one could not afford to stack the first cutting.

All the above calculations are for the first cutting and for Northern Colorado. The losses with the second cutting are much less, while the the third cutting has practically no loss.

C—ALFALFA ENSILAGE.

Some tests were carefully made on a small scale to see what losses might be expected in making ensilage of alfalfa. One test was made with the alfalfa put in whole as cut in the field, the other with the alfalfa cut to quarter inch pieces as we cut our corn for ensilage. The whole alfalfa showed a spoiled layer three inches thick on the top and an inch layer around the side nearly all the way down. The ensilage of the bottom and middle was excellent and was greedily eaten by the cows and calves. Its loss in the total weight was 10.7 per cent, but its loss in feeding value was probably a little larger.

The other silo was filled with cut alfalfa. The next day the silo was covered with two thicknesses of building paper and one of boards and weighted with stone to about fifty-five pounds per square foot. When coverd the ensilage was hotter than the hand could bear. Two days later the temperature had fallen to 83° F. and in two days more it had fallen to that of the air. The ensilage shrank and settled a good deal. When put in it contained 33.0 per cent of dry matter. On opening the silo showed two inches of spoiled ensilage on top and half an inch on the sides. The spoiled ensilage was 7.3 per cent of the total weight. The loss in dry matter was approximately ten per cent.

It is fair to presume that with a good tight silo, well made ensilage from cut alfalfa should not make a larger loss than was here given in our small experimental silo, or about ten per cent of its feeding value. To make good

ensilage from whole alfalfa is a much harder proposition. It requires that the alfalfa be quite green; that the silo be both tight and deep; that the alfalfa be thrown into the silo in small forkfuls and carefully tramped and that it be weighted by four to six feet of some heavy, tight packing material like cut corn fodder. If the alfala is put up in the middle of summer in clear, bright weather, it must be raked and loaded as fast as cut. One lot we tried was too dry for ensilage two hours after it was cut.

D—THREE METHODS OF HANDLING ALFALFA.

The preceding pages have given the losses that may be expected from handling alfalfa in the stack, in the barn and in the form of ensilage. Combining the losses in curing and gathering to those found in the stack and the barn, we can say that under the best of ordinary conditions, for every 100 pounds of feeding value as it exists in the green alfalfa at the time it is cut by the mower, 77 pounds will be saved if the hay is well cured and put in a stack under good conditions; 86 pounds will be saved if put in the barn, and 90 pounds can be expected if made into first-class ensilage. The cost of the ensilage is so much more than handling the alfalfa as hay that as between the silo and the barn there can be no question unless it is shown that the dry matter of the alfalfa ensilage has a higher feeding value, pound for pound, than that of the dry hay. In the comparison of the ensilage and the stacked hay, the principal advantage of the ensilage must lie in the fact that the alfalfa can be put in the silo, even under bad conditions of weather at time of cutting, and that once siloed it is safe from the worst weather.

E—TOP-DRESSING ALFALFA.

A field which had been in alfalfa three years was divided into five equal plots. The first, third and fifth were left as checks. The second plot was fertilized at the rate of sixty loads to the acre of fine, well rotted sheep manure. The fourth plot received half as heavy a top-dressing. The manure was spread on in the winter and after the alfalfa started in the spring, it was run over with a smoothing harrow to break up the manure fine and allow the alfalfa shoots a good chance to grow.

When the field was ready for the first cutting the eye

could detect a difference between the plots. Those which had been manured were a darker green, the stems were larger, taller and more succulent, but they did not seem to be so numerous as on the untreated plots. The whole field was cut the same day and the hay on each plot was hauled the same day.

FIRST CUTTING.

Plot.	Weight of hay.	Per cent of dry matter.	Weight of dry matter per plot.
1	3100	88.7	2750
2	3212	81.3	2611
3	3080	88.9	2738
4	3112	88.5	2764
5	3172	89.3	2838
Average 1, 3, 5	3117	88.9	2771
Average 2, 4,	3162	84.9	2685
SECOND CUTTING.			
1	1978	81.9	1609
2	2518	79.8	2009
3	1720	82.8	1424
4	1920	81.0	1555
5	1842	78.9	1453
Average 1, 3, 5	1847	81.2	1500
Average 2, 4,			
THIRD CUTTING.			
1	1100	83.2	915
2	1340	85.9	1151
3	970	88.7	860
4	1010	88.5	894
5	890	86.2	767
Average 1, 3, 5	987	86.0	849
Average 2, 4,	1175	86.0	1010
TOTAL CROP FOR THE YEAR.			
1	6178	85.4	5274
2	7070	81.6	5771
3	5770	87.0	5022
4	6042	86.3	5213
5	5884	85.9	5058
Average 1, 3, 5	5944	86.1	5118
Average 2, 4,	6556	83.8	5492
Difference in favor of fertilizing	612		374
Percentage Difference	10.3		7.3

CROP FOR THE SECOND YEAR.

Plot.	First Cutting.	Second Cutting.	Third Cutting.	Total Crop.
1	2240	1900	1240	5380
2	2490	1908	1394	5792
3	2000	1546	1158	4704
4	2170	1856	1458	5484
5	2170	1820	1458	5448
Average 1, 3, 5	2137	1755	1285	5177
Average 2, 4,	2330	1882	1426	5638
Difference in favor of fertilizing				461
Percentage difference				8.9

In both years the application of the fertilizer has apparently had a beneficial effect, but the result is not at all commensurate to the expense. Considering the manure itself as having no value, the mere hauling and spreading on the ground cost at the rate of more than thirty dollars per acre. The plots were close to an acre in size, so that the figures indicate a gain of about 500 pounds of hay or, at present prices, about a dollar's worth per acre.

No one could afford to top-dress alfalfa with the prospect of gaining only a dollar per acre per year. It seems probable that if it is desired to fertilize the land for alfalfa, that the land be plowed, the manure being turned to the bottom of the furrow, then the land cropped with corn and grain for one or two years and then seeded to alfalfa. We undertook to make this test, but the experiment was never completed.

In order to ascertain whether this heavy supply of plant food had made any difference in the chemical composition of the alfalfa, samples were analyzed of each of the cuttings of both the fertilized and unfertilized plots.

COMPOSITION OF DRY MATTER.

Cutting	Ash	Ether Extract	Crude Protein	Crude Fiber	Nitro-g'n-free Extract	Total Nitrg'n	Phos-phoric Acid	Potash
First, fertilized	11.29	1.54	13.88	35.74	37.55	2.22	0.59	3.09
Unfertilized	9.71	1.31	13.14	39.59	36.23	1.98	0.46	3.28
Second, fertilized	9.12	1.02	11.14	43.63	35.09	1.78	0.48	3.12
Unfertilized	8.95	1.04	11.08	45.22	33.71	1.78	0.36	2.31
Third, fertilized	10.90	1.19	14.58	36.74	36.51	2.33	0.47	2.75
Unfertilized	10.64	1.24	14.59	36.75	36.78	2.33	0.42	2.91
Average fertilized	10.47	1.25	13.20	38.70	36.38	2.11	0.51	2.99
Average unfertilized	9.77	1.21	12.97	40.52	35.59	2.03	0.41	2.83

The third cuttings are essentially duplicates. In the first and second cuttings the alfalfa from the fertilized plots has a higher feeding value and is richer in plant food. These differences are large enough so as to make it probable that the results are not accidental, but are due to real differences of composition caused by the application of the fertilizer.

F—MOISTURE IN GREEN ALFALFA.

The actual amount of water in alfalfa at the moment the mower knife cuts it, we have tested but little, as this has hardly any practical bearing, but we have made several tests of how much moisture it holds about an hour later, that is, in the condition it would be if put in the silo. One test the last week in May gave 76.8 per cent of water, or 23.2 per cent of dry matter. Four tests the third week in June gave 69.7, 67.0, 75.6, 72.8 with an average of 71.3 per cent of water, which is just about right for the best results in the silo.

A sample cut in September, in bright drying weather, was dried to 62.0 per cent water in an hour, too dry to be put in the silo, while a sample as actually put in the silo in October during cloudy weather was 74.0 per cent water.

G—MOISTURE IN ALFALFA HAY.

Few farmers realize how much water there is in what they call dry hay.

It is impossible to dry out all the water from hay without resorting to artificial heat. Hay spread out in a thin layer in direct sunlight and sheltered from all rain and dew will finally dry out until a hundred pounds of hay contains only five pounds of water. This is as dry as it can be gotten without the use of a regular drying oven.

In Colorado "air dry" means with about ten per cent of water; that is, if hay is stored in a barn and sweats and drys out thoroughly, a hundred pounds will contain about ten pounds of water. Oats and wheat in the bin late in the winter contain about the same amount of water, while corn in the crib will contain by the next spring about the same ten per cent of water.

But the "well cured" hay, as usually put in the stack or the barn, is far from these conditions. In the course of our experiments we have had occasion to test the moisture of thirty-five samples of hay taken in different years and representing the three cuttings.

Three samples taken in June tested 23.2, 30.0 and 26.3 per cent of water, with an average of 26.5 per cent and they heated quite badly, becoming dusty and a little darkened. Seventeen samples that kept well tested 14.0, 13.0, 9.3, 11.2, 20.6, 22.7, 22.9, 17.1, 19.4, 17.8, 15.2, 23.1, 11.0, 10.8, 10.4, 18.4, 11.7 per cent with an average of 15.2 per cent of water. The dryest of these with 9.3 per cent of water is too dry,

being so brittle as to lose too much in handling, while the wetter ones 20.0 per cent and above will probably contain some forkfuls that are too wet and will make the hay dusty. From 15 to 18 per cent of water is about right for the proper handling of the hay and its settling in the stack so as to shed rain. This means that the hay will lose about one-fourteenth of its weight of water in drying out in the stack, besides its loss from fermentation and washing.

The samples of hay from the second cutting contained 22.0, 24.0 and 24.0 per cent water and heated somewhat. Five samples contained 16.8, 18.9, 15.9, 17.7, 19.8 with an average of 17.8 per cent of water and all kept well.

Five samples of hay from the third cutting tested 15.5, 13.8, 11.0, 11.2, 13.5 averaging 1.30 per cent of water and all kept in excellent shape.

II. CORN.

A—SILO NOTES.

The very cheaply built silo described in a former bulletin of this station was filled with fodder corn. In one of the four compartments the top layer was composed of about a ton of corn, and the covering consisted of a layer of wet straw and then about four inches of wet dirt. The top layer was spoiled for a little over two inches. This and the covering make a weight for the second layer of about sixty pounds per square foot. This second layer contained 9997 pounds of corn fodder at the time of filling. When opened and fed out the last of December it weighed just a thousand pounds less, or a loss of ten per cent. The layer next under this shrank from 9721 pounds put in, to 9409 pounds taken out—a loss of but three per cent. The most expensive silo could not preserve corn with a less loss.

When the silo was filled the corn was separated into four layers by boards,and rods of known lengths were firmly attached to these board partitions, so that as the boards settled the thickness of the layers would be known from the height of the rods.

The silo was ten feet square and the bottom layer contained 6588 pounds of fodder corn cut into quarter inch pieces. When on top of this layer one more load had been

placed and well tramped, that is, half an hour later with a weight of fifteen pounds to the square inch, the layer was 34½ inches thick, giving a weight of 23 pounds to the cubic foot. In another hour, with a weight on top of 95 pounds to the square foot, the layer had been squeezed five inches thinner and weighed 27 pounds to the cubic foot. The next morning with an average pressure of about 213 pounds to the square foot, the layer weighed 31 pounds to the cubic foot. During the next two days the silo was filled up, covered with wet straw, allowed to stand four days and then covered with wet dirt. This gave an average pressure of 323 pounds to the square foot. Three days later, that is ten days after the corn was put in the silo, the bottom layer had settled 7 inches to 18½ inches thick, or 44 pounds to the cubic foot. Six weeks later it had settled two inches more and another inch in the next month. It then weighed 50.7 pounds to the cubic foot. When the pressure was removed by the throwing out of the upper layers, this bottom layer expanded one inch from 15½ to 16½ inches, or from 50.7 pounds to the cubic foot to 47.9 pounds.

The next to the bottom layer contained 9721 pounds of fodder corn. An hour after it was put in the silo, when it was weighted 35 pounds to the square foot, it made a layer 58 inches thick, or 20 pounds to the cubic foot. By the next day at noon, with 125 pounds of weight to the square foot, the layer had been reduced to 48 inches thick or 24 pounds to the cubic foot. At the end of eight days, with an average pressure of 244 pounds per square foot, it had shrunk a quarter more and weighed 31 pounds to the cubic foot. Ten weeks later, when the bottom layer weighed 50.7 pounds to the cubic foot, this layer weighed but 33.3 pounds. One had a pressure of 244 pounds and the other 323 pounds per square foot and the one with the lighter pressure is the heavier proportional to the pressure.

The third layer from the bottom contained 9997 pounds fodder corn. An hour after it was put in, with a pressure of 25 pounds per square foot, it was 57 inches thick or 21 pounds to the cubic foot. Eight days later, with an average pressure of 145 pounds per square foot, the layer was 39.5 inches thick, 30.3 pounds per cubic foot. Here, again, the weight per cubic foot is not proportional to the pressure. It did not change from this weight, compressing only to 31.5 pounds per cubic foot at the lowest. When the cover and upper layer were removed the top of this third layer rose two and a half inches, this being the amount that the whole mass of the three layers below expanded. This expansion seemed to be one inch for the first and third layers and half

an inch for the middle layer. As the three layers together were 88 inches thick, the expansion was but three per cent when a weight of 95 pounds per square foot was removed.

The three layers together were 88 inches thick and averaged 36 pounds per cubic foot with a pressure above 95 pounds per square foot, or an average pressure for the whole of 226 pounds per square foot. It has been estimated that it requires a pressure of about 1500 pounds per square foot or about ten pounds to the square inch to compress ensilage to its least possible bulk, when it will weigh nearly 64 pounds to the cubic foot. This is on supposition that the fodder corn is properly matured. The greener the corn the more it will weigh to the cubic foot with small pressures and the less pressure it will take to force out the last of the air.

B—SEED CORN FROM DIFFERENT ALTITUDES AND LATITUDES.

A test was made extending over four years to see whether the altitude or latitude of the place at which the seed was grown would have any effect on the yield when planted in Colorado. Or, to put the problem in a little different words, to see whether Colorado grown seed was better or poorer than that grown further east. The two varieties, Pride of the North and Leaming, were selected for the test since they are the largest corn that will ripen at Fort Collins, and the seed is handled by most of the large seed dealers. Fort Collins is out of the main corn belt so that none of the yields are so high per acre as are commonly obtained in the Mississippi Valley, nor nearly so large as would be grown in the Arkansas Valley in this State. But the principle of comparison is the same, even with the smaller yields. The following tables give the weight per acre of the whole crop or what it would yield if grown for ensilage and also the weight per acre of shelled corn.

WEIGHT OF WHOLE CROP PER ACRE.

Pride of the North.

State	Firm	1895 lbs.	1897 lbs.	1898 lbs.	1899 lbs.	Aver'ge lbs.
Nebraska	Nebraska Seed Co	14250	....	....	....	14250
Colorado	Lee-Kinsey	18500	16000	6375	12666	13385
"	Barteldes & Co	14875	....	8600	14833	12569
Pennsylvania	W. H. Maule	20625	....	....	....	20625
Illinois	Vaughn Seed Store	18875	....	....	....	18875
Colorado	Matthews	16750	....	....	....	16750
Iowa	Iowa Seed Co	....	17500	6625	6538	10221
Minnesota	Northrop King & Co	....	10666	3250	7142	7019
Illinois	J. Bauscher	....	14416	10500	7602	10839
Minnesota	L. L. May Co	....	13500	6500	12934	10978
Pennsylvania	W. A. Burpee	....	10833	6000	8111	8314
Ohio	Storrs Harrison & Co	....	12416	5875	9818	9369
New York	J. M. Thorburn	....	21750	10000	15522	15757
Illinois	H. W. Buckbee	....	11083	3125	7659	7289
Michigan	D. M. Ferry	....	3250	6125	8653	6009

WEIGHT OF SHELLED CORN PER ACRE.

Pride of the North.

State	Firm	1897 lbs.	1898 lbs.	1899 lbs.	Aver'ge lbs
Iowa	Iowa Seed Co	2000	900	1730	1543
Minnesota	Northrop King & Co	1833	652	2261	1582
Colorado	Lee-Kinsey	1000	795	2666	1487
Illinois	J. Bauscher	1333	1656	2142	1710
Minnesota	L. L. May Co	1416	840	2375	1543
Pennsylvania	W. A. Burpee	1250	997	2000	1415
Ohio	Storrs Harrison & Co	750	787	2000	1179
New York	J. M. Thorburn	2166	735	2537	1812
Illinois	H. W. Buckbee	1583	850	2128	1520
Michigan	D. M. Ferry	166	1087	2596	1283
Colorado	Barteldes & Co	....	840	2166	1503

Leaming.

WEIGHT OF WHOLE CROP PER ACRE.

State	Firm	1895 lbs.	1897 lbs.	1898 lbs.	1899 lbs	Aver'ge lbs.
Nebraska	Nebraska Seed Co	19250	....	....	....	19250
Pennsylvania	D. Landreth	18500	18416	....	13500	16805
"	W. H. Maule	20875	14833	7500	17900	15277
Illinois	Vaughn Seed Store	17000	....	....	....	17000
Iowa	Iowa Seed Co	....	20250	11000	15319	15523
Minnesota	Northrop King & Co	19625	21083	6750	10769	14566
California	Cox Seed Co	....	20833	6000	14318	13717
Colorado	Barteldes & Co	15125	27750	10000	6018	14723
Massachusetts	R. & J. Farquhar	....	23250	....	13205	18228
Minnesota	L. L. May Co	....	24833	8250	15925	16336
Wisconsin	J. A. Salzer	....	24333	9375	13921	15876
Pennsylvania	W. A. Burpee	....	20166	2375	13571	12204
Ohio	Storrs Harrison & Co	....	20166	8000	15106	14424
New York	J. M. Thorburn	....	17333	4875	12708	11638
Illinois	H. W. Buckbee	....	22000	6875	14411	14428
Massachusetts	J. J. H. Gregory	....	25416	10250	13921	16529
Pennsylvania	Johnson Stokes & Co	....	14750	4000	14857	11202

Leaming.

WEIGHT OF SHELLED CORN PER ACRE.

State	Firm	1897 lbs.	1898 lbs.	1899 lbs.	Aver'ge lbs.
Iowa	Iowa Seed Co	1750	1182	2659	1864
Minnesota	Northrop King & Co	2250	945	2692	1962
California	Cox Seed Co	2000	575	2613	1729
Colorado	Barteldes & Co	1666	340	1481	1296
Massachusetts	R. & J. Farquhar	2083	....	1923	2003
Pennsylvania	D. Landreth	1750	....	1800	1775
Minnesota	L. L. May Co	2000	822	2692	1838
Wisconsin	J. A. Salzer	2083	537	1764	1461
Pennsylvania	W. A. Burpee	1750	....	1982	1866
"	W. H. Maule	666	472	3000	1379
Ohio	Storrs Harrison & Co	1166	591	2021	1259
New York	J. M. Thorburn	2000	505	1458	1321
Illinois	H. W. Buckbee	2083	577	2745	1801
Massachusetts	J. J. H. Gregory	2750	618	2058	1809
Pennsylvania	Johnson Stokes & Co	1416	410	2142	1323

The results are not at all uniform, but it seems possible to draw the conclusions that the seed grown in Colorado produces just about the average of that grown in all the other states for Pride of the North, and less than the average for the Leaming. The northern grown seed shows poorly for Pride of the North and among the best for the Leaming. The eastern grown seed Massachusetts, Pennsylvania and New York on the whole gives better returns than that grown west of the Mississippi river.

C—VARIETY TESTS OF CORN.

For the past six years there have a large number of the principal varieties of corn been grown on the college farm. It is believed that the results of so long a test will prove valuable as giving a clear indication of the general kind and size of corn that will do the best under the given conditions of altitude and latitude. All grades were tested, from the Will's Gehu that ripens long before frost and bears its ears less than a foot from the ground, to the Giant Mexican June that sends out its silk as high as a man can reach and is barely tasseling at the usual harvest time.

In all cases the corn was planted in hills three feet apart each way. In 1895 it was not irrigated and the crop was small. The other years the corn was irrigated twice. The land on which this corn was grown was a different field each year and was for the most part on ground that had been heavily manured. In all cases it was land so rich and in such condition that it would have raised a large crop of grain. In other words the small crops are due to the climate rather than the soil, and show that Fort Collins is outside of the corn belt. Still, corn will grow here so well that if it was not for the ease and cheapness with which alfalfa can be grown, corn would be the cheapest fodder for dairy stock.

VARIETY TESTS OF CORN 1894.

Variety.	Total Crop per acre.	Green Ears per acre.	Green Stover per acre.	Shelled Corn per acre.
Flint Corn—				
Golden Dew Drop..	16,800	4,820	11.980	1,926
Will's Gehu	14,200	4,900	9,300	2,117
King Philip.........	19,200	3,600	15,200	1,028
Sanford	23,400	5,300	18,100	1,809
Longfellow	19,600	3,850	15,750	1,327
Minn. King.........	14,200	2,900	11,300	1,176
Dent Corn—				
Queen of the Field..	22,800	6,300	16,500	1,686
Huron..............	18,400	5,423	12,977	2,408
White Pearl	21,400	6,869	14,531	2,408

Variety.	Total Crop per acre.	Green Ears per acre.	Green Stover per acre.	Shelled Corn per acre.
Wis. Yellow Dent...	21,600	5,900	15,700	2.167
Pride of the North..	24,800	5,800	19,000	1,809
Cali. Yellow.........	22,400	6,250	16,150	1,926
Mastodon...........	25,000			
Chester County Mam.	21,200			
Red Cob...........	23,200			
Champ. Co. Prolific..	23,000			
Leaming...........	30,800			
Giant Fodder.......	35,000			
Va. Mammoth.......	20,800			

VARIETY TESTS OF CORN 1895.

Flint Corn—			
Golden Dew Drop...	12,100	2,600	9,500
Will's Gehu	7,875	3,750	4,125
King Philip.........	13,000	3,100	9,900
Sanford	14,750	4,375	10,375
Longfellow	14,200	2,000	12,200
Minn. King	13,000	3,900	9,100
White Australian ...	18,600	6,500	12,100
Angel of Midnight..	12,600	2,000	10,600
Yellow Australian ..	10,700	4,700	6,000
Colorado White.....	25,100	4,400	20,700
Brazilian Flour	18,000	....	18,000
Dent Corn—			
King of the Earliest.	20,400	3,900	16,500
Queen of the Field..	18,500	5,500	13,000
Huron..............	12,100	3.800	8,300
White Pearl	14,700	1,900	12,800
Pride of the North ..	17,500	4,000	13,500
Gold Mine..........	18,000	4,500	13,500
White Cap Dent....	17,000	2,300	14,700
Grafflin.............	15,700	4,000	11,700
Riley's Favorite.....	19,000	2,700	16,300
Mastodon...........	15,250	1,751	13,500
Red Cob............	20,000	....	20,000
Leaming............	18,400	3,750	14,650
Giant White Dent...	18,400	2,200	16,200
Conqueror	7,000	900	6,100
Mam. Cuban........	20,400	4.400	16,000
Mam. Red	20,500	4,500	16,000
Giant Mex. June....	13,600	....	13,600
Swadley	11,100	4,900	6,200
Golden Row	20,700	2,700	18,000
Golden Beauty......	22,200	3,700	18,500
Nebr. White Prize ..	17,400	3,200	14,200
Early California .. .	21,000	4,000	17,000
Golden Seal	23,700	5,200	18,500
Hathaway's Yel. Dent	18,700	8,500	10,200
Evergreen Sweet....	15,600	3,400	12,200

VARIETY TESTS OF CORN 1896.

Flint Corn—				
Golden Dew Drop..	24,500	3,750	21,750	1,670
Will's Gehu........	9.300	4,100	5.200	2,330
King Philip.........	19,250	3,830	15,420	1,900
Sanford	24,100	4,500	19,600	1,417
Longfellow	25,800	2,580	23,220	1,090
White Australian...	19,500	6,100	13.400	3,000
Angel of Midnight..	16,100	1,600	14,500	400
Yellow Australian...	6,800	2,300	4.500	1,100
Colorado White.....	27,600	4,700	22,900	1,400

Variety.	Total Crop per acre.	Green Ears per acre.	Green Stover per acre.	Shelled Corn per acre.
Brazilian Flour	44,500	....	44,500	....
Dent Corn—				
Queen of the Field	22,200	6,250	15,950	2,750
White Pearl	20,500	2,700	17,800	500
Pride o the North	19,700	4,600	15,100	2,250
Dakota Dent	16,000	4,000	12,000	1,900
Gold Mine	17,500	4,800	12,700	....
White Cap Dent	24,700	4,900	19,800	....
Grafflin	17,800	4,000	13,800	1,600
Riley's Favorite	20,300	2,700	17,600	....
Mastodon	18,200	3,250	14,950	1,000
Red Cob	33,200	3,900	29,300	....
Leaming	18,700	4,400	14,300	2,400
Giant White Dent	16,600	1,600	15,000	250
Conquerer	14,400	1,600	12,800	....
Mam. Cuban	21,100	5,200	15,900	1,900
Mam. Red	19,000	3,200	15,800	....
Giant Mex. June	84,000	....	84,000	....
Swadley	10,800	3,800	7,000	2,000
Golden Row	31,000	5,700	25,300	1,900
Golden Beauty	27,200	5,300	21,900	....
Neb. White Prize	22,700	3,100	19,600	750
Early California	24,100	3,700	20,400	....
Golden Seal	13,200	3,400	9,800	1,300
Hathaway's Yellow Dent	18,100	6,100	12,000	....
Evergreen Sweet	20,700	1,700	19,000	500
VARIETY TESTS OF CORN 1897.				
Flint Corn—				
Sanford	13,750	2,667	11,083	1,250
Longfellow	16,861	2,917	13,944	1,139
White Australian	15,583	4,333	11,250	2,250
Angel of Midnight	16,000	4,083	11,917	1,750
Squaw Corn	7,167	3,000	4,167	2,083
Compton's Early	17,250	2,917	14,333	1,417
Earliest Ripe	4,416	2,083	2,333	1,250
Early Canada	12,666	2,833	9,833	1,333
Minn. White Flint	17,666	4,583	13,083	2,250
Red-blazed	9,750	1,500	8,250	750
Pride of Canada	13,000	2,250	10,750	1,167
Brazilian Flour	21,500	....	21,500	....
White Flint	14,583	3,250	11,343	1,167
Dent Corn—				
Pride of the North	14,242	3,371	10,871	1,568
Dakota Dent	8,666	3,083	5,583	1,416
Huron	17,333	3,583	13,750	1,833
Gold Mine	17,333	3,250	14,083	1,417
Grafflin	12,333	2,333	1,000	2,000
King of the Earliest	20,083	3,667	16,416	1,667
Iowa Silver Mine	18,667	3,167	15,500	1,167
Red Cob	40,333	7,583	32,750	2,333
Leaming	21,028	4,589	16,439	1,761
Cuban Giant	17,333	1,917	15,417	500
Giant Mex. June	44,417	.....	44,417	.....
Swadley	12,500	3,250	8,250	1,583
Golden Beauty	20,875	3,792	17,083	1,209
Evergreen Sweet	20,667	3,000	17,667	750
Blount's Mammoth	25,167	4,500	20,667	1,250

VARIETY TESTS OF CORN, 1898.

Variety.	Total Crop per acre.	Green Ears per acre.	Green Stover per acre.	Shelled Corn per acre.
Flint Corn—				
Sanford	7,125	1,125	6,000	
Longfellow	6,708	1,333	5,375	
Angel of Midnight	8,500	1,500	7,000	
Squaw Corn	5,375	3,250	2,125	
Compton's Early	7,500	1,250	6,250	
Early Red Blazed	6,750	1,500	5,250	
Pride of Canada	10,625	2,000	8,625	
Dent Corn—				
Pride of the North	6,438	1,750	4,688	930
Dakota Dent	3,125	1,500	1,625	
Early Huron	5,625	1,750	3,875	
Gold Mine	8,625	2,375	6,250	
Grafflin	5,875	2,250	3,625	
King of the Earliest	8,125	1,375	6,750	
Silver Mine	11,875	2,250	9,625	
Red Cob	12,125	375	11,755	
Leaming	7,365	1,448	5,917	642
Cuban Giant	8,375	750	7,625	
Giant Mexican	9,750	....	.....	
Evergreen	4,500	500	4,000	
Blount's Mammoth	5,875	....	.....	

VARIETY TESTS OF CORN, AVERAGE OF 1894–1898.

Variety.	Total Crop per acre.	Green Ears per acre.	Green Stover per acre.	Shelled Corn per acre.
Flint Corn—				
Golden Dew Drop	17,800	3,723	14,808	1,798
Will's Gehu	10,458	4,250	6,208	2,857
King Philip	17,150	3,510	13,640	1,464
Sanford	16,625	3,593	13,032	1,492
Longfellow	16,634	2,536	14,098	1,185
Minn. King	13,600	3,400	10,200	1,176
White Australian	17,894	5,644	12,250	2,625
Angel of Midnight	13,400	2,296	11,104	1,025
Yellow Australian	8,750	3,500	5,250	1,100
Colorado White	26,350	4,550	21,800	1,400
Brazilian Flour	28,000	.....	28,000	.....
Squaw Corn	6,271	3,125	3,146	2,083
Compton's Early	12,375	2,084	10,291	1,417
Earliest Ripe	4,416	2,083	2,333	1,250
Early Canada	12,666	2,833	9,833	1,333
Minn. White Flint	17,666	4,583	13,083	2,250
Red-blazed	8,250	1,500	6,750	750
Pride of Canada	11,813	2,125	9,688	1,167
White Flint	14,583	3,250	11,333	1,167
Dent Corn—				
Queen of the Field	21,167	6,017	15,150	2,218
Huron	14,115	3,639	10,476	2,121
White Pearl	18,867	3,823	15,044	1,954
Wis. Yellow Dent	21,600	5,900	15,700	2,167
Pride of the North	16,536	3,904	12,632	1,639
Cal. Yellow	22,400	6,250	16,150	1,926
Mastodon	19,483	2,500	16,983	1,000
Chester Co. Mam	21,200	.....	......	.....
Red Cob	25,772	3,953	21,819	2,333
Champ Co. Prolific	23,000	.....	......	.....
Leaming	19,259	3,547	15,712	1,601
Giant Fodder	35,000	.....	......	....
Va. Mammoth	20,800	.....	......	.....
King of the Earliest	16,203	2,981	14,222	1,667
Gold Mine	15,365	3,731	11,634	1,417
White Cap Dent	20,850	3,600	17,250	.....

Variety.	Total Crop per acre.	Green Ears per acre.	Green Stover per acre.	Shelled Corn per acre.
Grafflin	12,927	3,146	9,781	1,800
Riley's Favorite	19,650	2,700	16,850	.....
Giant White Dent	17,500	1,900	15,600	250
Conqueror	10,700	1,250	9,450	.....
Mam. Cuban	20,750	4,800	15,950	1,900
Mammoth Red	19,750	3,850	15,900	.....
Giant Mex. June	37,942	.....	37,942	.....
Swadley	11,467	3,983	7,484	1,792
Golden Row	25,850	4,200	21,650	1,900
Golden Beauty	23,425	4,264	19,161	1,209
Neb. White Prize	20,050	3,150	16,900	750
Early California	22,550	3,850	18,700	.....
Golden Seal	18,450	4,300	14,150	1,300
Hathaway's Yellow Dent	18,400	7,300	11,100	.....
Evergreen Sweet	15,367	2,150	13,217	625
Dakota Dent	9,264	2,861	6,403	1,658
Iowa Silver Mine	15,271	2,709	12,562	1,167
Cuban Giant	12,854	1,334	11,520	500
Blount's Mammoth	15,021	4,500	10,521	1,250

D—NUMBER OF STALKS IN A HILL.

The effect on the yield of the corn, of a different number of stalks in a hill, was noted two different years. The first year the crop was rather larger than an average crop in this part of Colorado. The number of stalks in each hill was counted and the weight of each hill recorded. Omitting the outside rows leaves 320 hills, which were divided as follows:

No. of Stalks Per Hill	No. of Hills containing this No. of Stalks	Per Cent of Total No. of Hills	Total Weight	Average Weight Per Hill	Average Weight Per Stalk
0	76	24	0	0	0
1	22	7	60	2.7	2.7
2	30	9	133	4.4	2.2
3	52	16	284	5.5	1.8
4	56	17	397	7.1	1.8
5	47	15	375	8.0	1.6
6	29	9	260	9.0	1.5
7	6	2	53	9.0	1.3
8	1	0	11	11.0	1.4
Av. and Total..3	320	100	1513	4.7	1.6
Omitting missing hills......4	244		1513	6.2	1.6

It will be noted that as the number of stalks in a hill increases, the size of each stalk diminishes, but the increase in number much more than overbalances the decrease in size and the weight of the hill is greater the larger the number of stalks. A hill containing six stalks weighs much more than a hill of one stalk, but instead of weighing six times as much, it weighs a little more than three times as much.

The same principle is seen the second year when a larger number of hills was weighed from a field having rather less than an average crop in size.

No. of Stalks Per Hill	No. of Hills containing this No. of Stalks	Per Cent of Total No. of Hills	Total Weight	Average Weight Per Hill	Average Weight Per Stalk
0	107	14	0	0	0
1	58	7	97	1.7	1.70
2	130	16	339	3	1.50
3	271	35	1053	3.9	1.30
4	162	21	687	4.2	1.05
5	46	6	243	5.3	1.06
6	10	1	62	6.3	1.05
Average and Total,	784	100	2533	3.5	1.22
Omitting missing hills	677	86	2533	4.1	1.22

There is no indication in the figures of either year as given in this form that the increase could not go on indefinitely. The larger the number of stalks the larger the weight of the hill seems to be the rule. But there really is a limit. If each hill was by itself with plenty of space on all sides,the above rule would be true. When, however, the hills are only three feet apart, as was the case in these fields, there is room for only a certain number of stalks to grow and develop on a given area. The addition of one more plant to a hill not only decreases the size of the other plants in that hill, but it also decreases the size of each of the four hills surrounding it. If these several losses amount to more than the weight of the extra plant, then its presence in the field is a positive loss. For each field there is such a point and when that point is reached is the number of stalks per hill that gives the largest yield of crop per acre. To learn what this number is, the number of stalks in the four hills next to each hill was then counted and the weight of the hill recorded. Combining these data and interpolating to get even numbers, gives the results below;

No. of stalks in a hill.	Average No. of stalks in the 4 hills about it.	Weight of the hill lbs.	Weight per acre tons.
1	1	3.5	8.7
	3	2.6	6.2
2	2	4.6	11.5
	3	4.5	11.2
3	3	5.4	13.5
	4	4.6	10.5
4	3	6.8	17.0
	4	6.2	15.5
	5	5.9	14.7
5	3	8.0	20.0
	4	8.0	20.0
	5	7.6	19.0
6	5	7.3	18.2
	6	7.0	17.5

From the last table we can estimate the yield per acre from the different number of stalks in a hill:

6	stalks	per hill	give a	crop of	17.5	tons	per acre
5	"	"	"	"	19.0	"	"
4	"	"	"	"	15.5	"	"
3	"	"	"	"	13.5	"	"
2	"	"	"	"	11.5	"	"
1	"	"	"	"	8.7	"	"
Half 4 stalks and half 5 stalks					17.0	"	"

If the hills are equally divided among the different numbers from one to six, the resulting crop would be about 14.0 tons per acre.

These figures show that in this field the largest crop would be obtained from five stalks in each hill. If a hill contained six stalks, with five stalks in each hill surrounding it, the extra stalk caused a net loss of about a third of a pound per hill, showing but slight loss, while if it contained four stalks, or one less than the best number, the net loss was 1.7 pounds per hill.

The next year shows some unexpected figures. It had been supposed that with a lighter crop of smaller stalks, the field would support a greater number of stalks, but the figures do not seem to warrant this conclusion.

No. of stalks in a hill.	Average No. of stalks in the 4 hills around it.	Weight of the hill lbs.	Weight per acre tons.
1	1	2.12	5.3
	3	1.57	3.9
2	2	3.31	8.3
	3	2.80	7.0
3	3	3.94	9.8
	4	3.45	8.6
4	3	4.66	11.6
	4	4.57	11.4
	5	4.21	10.5
5	3	5.01	12.5
	4	4.52	11.3
	5	3.87	9.7

It is evident here that the largest crop is one that has four stalks in each hill, since the weights with the different numbers of stalks give:

5	stalks	per hill	give a	crop of	9.7	tons	per acre
4	"	"	"	"	11.4	"	"
3	"	"	"	"	9.8	"	"
2	"	"	"	"	8.3	"	"
1	"	"	"	"	5.3	"	"

Since this field gives a smaller crop per acre from smaller stalks, and yet gives a larger return from four stalks in a hill than from five stalks, it cannot be said that it is always better to have less stalks in a hill, the larger the variety of corn.

Since these two crops represent a good share of the crops of northern Colorado, it can be said that where corn is raised for fodder four or five stalks in a hill, if the hills are three feet apart each way, gives the largest crop per acre.

E—MISSING HILLS IN A CORN FIELD.

One of the largest sources of loss in the cornfield is hills without any stalks. In the field of corn grown the first year, it was thought that there were not enough hills missing to pay for replanting, but when harvest came, the count showed 24 per cent missing or a loss in this field of about two and half tons of fodder corn, or much more than enough to have paid for the replanting.

In figuring the loss from a missing hill, two items have to be taken into account, the loss from the hill itself and the gain to the hills around it.

The first is easily told by taking the average weight of the hills which are surrounded by four full hills. The second is not so easy to ascertain. One way of estimating is to get the average weight of those hills that are next to a missing hill and compare this weight with the weight where the hills are full.

In the field the first year there were 114 hills which had a missing hill on one side of them, with an average weight 6.8 pounds. The 122 hills that were surrounded by complete hills average 6.0 pounds. This indicates an average gain of 0.8 pounds to each of the four hills surrounding a missing hill or a total gain of 3.2 pounds. But since the average weight of the hill in this field was 6.0 pounds, each hill that was missing meant a loss of 6.00 pounds and a gain of 3.2

pounds or a net loss of 2.8 pounds which is equal to 47 per cent.

The same thing was tried in another field of much heavier corn. The 165 hills surrounded by four full hills averaged 10.11 pounds each or fully twenty-five tons of fodder corn per acre. The 248 hills that were next to a missing hill averaged 10.77 pounds; a gain of 0.66 pounds for each of the four surrounding hills, making a gain of 2.64 pounds. The loss for each missing hill is 10.11 pounds and the gain 2.64 pounds, at a net loss of 7.47 pounds or 74 per cent.

Another field of rather light corn gave somewhat different results. The 216 hills near a missing hill weighed 4.27 pounds and the 392 hills fully surrounded weighed 3.52 pounds each. Here is a gain of four times 0.75 pounds or 3.00 pounds as compared with a loss of 3.52 pounds or a net loss of but 0.52 pounds equal to 15 per cent.

The three fields show most widely different results and it is evident that these differences are due to the different vigor in the growth of the crop. When a crop is of such a large rank growing variety as in the second case, and there are stalks enough in the hill to produce the maximum growth, the ground is so full of roots, that even the loss of a hill does not open up enough extra ground to add much to the weight of the surrounding hills compared with the large growth there already. While in a field with a small crop the result is relatively larger. In absolute weight of effect, a missing hill has closely the same result in all three fields. In the field with the light crop it makes a gain of 0.75 pounds for each of the four hills surrounding it; in the field of medium growth the gain is 0.80 pounds per hill and in the field with the very heavy growth 0.66 pounds per hill. The average of these is 0.74 pounds for each hill or about 3.00 pounds for the four surrounding hills. It can be said then that in general a missing hills makes a gain of about three pounds of cornfodder in the weight of the surrounding hills and a loss of the weight of an average hill of the field.

III. POTATOES.

A—ALFALFA SOD COMPARED WITH OLD LAND.

A test was made of potatoes on alfalfa sod as compared with good land that had been manured two years before and raised one crop of grain and one of corn. There were nine plots of each and though the plots are quite variable, in each case the alfalfa sod gives a larger yield than the old ground. In the plots which are the nearest alike, the yield from alfalfa sod is not quite twice that from the old ground, while in two other plots it is five times as much. The average is about three to one, being 3601 pounds of merchantable potatoes from the alfalfa sod and but 1277 pounds from the old ground.

B—EXPERIMENTS WITH FERTILIZERS,

Experiments in fertilizing the ground for potatoes were made with a complete fertilizer and with kainit, sulphate of potash and muriate of potash. The complete fertilizer was bought in Denver at forty dollars per ton; the potash salts came from the Potash Trust of New York City. The fertilizer was applied at the rate of four hundred pounds per acre.

Plot.	Fertilizer.	Yield of potatoes.
1	Nothing	431
2	Sulphate of potash	430
3	Muriate of potash	488
4	Complete fertilizer	576
5	Kainit	665
6	Nothing	689
7	Sulphate of potash	628
8	Muriate of potash	610
9	Complete fertilizer	409
10	Kainit	383
11	Nothing	273

Combining the plots gives the following averages :

Sulphate of potash	1058	pounds
Muriate of potash	1098	"
Complete fertilizer	985	"
Kainit	1048	"
Nothing	896	"
Average of fertilized plots	1047	"
Average of unfertilized plots	896	"
Gain from fertilization	14 per cent.	

Under ordinary prices this gain of fourteen per cent would just about pay the cost of the fertilizer, but it is evident that part of the difference in crop is due to differences in the character of the ground, so that it would be hardly safe to say that the whole of the gain of fourteen per cent was due to the fertilizer.

IV. SUGAR BEETS.

A—SUBSOILING FOR SUGAR BEETS.

A test was made of the effect of subsoiling the land for sugar beets as compared with simple plowing. The subsoiling was done with a Secretary plow to the depth of fourteen inches, the rest was plowed eight inches deep with a common stirring plow. The field was divided into six equal strips, alternately plowed by the two methods. The field was subsoiled in May and planted the same day. The results are given in the following table:

Plot.	Treatment.	Crop Per Plot.
1	Plowed	2960
2	Subsoiled	6880
3	Plowed	5860
4	Subsoiled	4554
5	Plowed	4040
6	Subsoiled	4400

The average of the three plots merely plowed is a crop of 4287 pounds of sugar beets, while the three plots subsoiled gave a crop of 5278 pounds. This is an apparent increase of 23 per cent as the result of subsoiling.

A second trial made in the same way with four plots gave

Plot.	Treatment.	
1	Plowed	2340
2	Subsoiled	2300
3	Plowed	1470
4	Subsoiled	1956

The average of the plowed plots is 1905 pounds and of

the subsoiled 2128 pounds, being a difference of 12 per cent in favor of the subsoiled.

The average of the whole ten tests is 18 per cent gain in weight of the crop as the result of subsoiling.

B—SUGAR BEETS IN COLORADO IN 1899.

The results of the experiments with sugar beets in 1897 and 1898 have already been published in former bulletins of this Station. In 1899 the work was not conducted on so large a scale. It was considered that the results of 1898 showed beyond a shadow of a doubt that there were large areas in Colorado that were adapted to the raising of large crops of excellent beets for factory use and that therefore there was no further need of making general distributions of seed for testing this point.

The questions to be considered hereafter are the more special points of how to handle the crop to get the best results. The season of 1899 was devoted to the study of questions concerning the proper time to plant, the best distance between the rows and whether or not the seed should be irrigated at the time of planting. With regard to the first, the results are decisive and that question may be considered as settled. The second was decided, so far as the test went, but the problem is yet left of still closer distances. The third problem was not solved and it remains as one of the two large problems yet to be attacked in Colorado. The solving of either would mean a gain of more money each year to Colorado than the total received from the government for carrying on experimental work. The first problem, broadly stated, is: How shall the irrigation water be handled to obtain a full stand of beets. The second problem is at the other end of the season: What can be done to make the beets ripen thoroughly?

I. TIME OF PLANTING.

Seed was sent to several parties representing the principal beet growing sections of the State with the request that they make four plantings conforming as nearly as convenient to the dates April 15, May 1, May 15 and June 1. The work was done on small plots so as to eliminate so far as possible differences of soil and irrigation and to allow the work to be done with great care. The returns show that the stand of beets was almost perfect in every case and that the crops were large in quantity and of good quality.

The first table gives the facts concerning the planting

and the second the returns of the harvest. The rows in each case were twenty-four inches apart. In this test and in all the others the seed was sent to the growers from the College and was in each case the Zehringen furnished by the Department of Agriculture at Washington.

RECORDS OF PLANTING.

Name	Place	DATE OF EACH PLANTING.				Date of harvest
		First	Second	Third	Fourth	
M. D. Parmenter	Lamar	April 10	May 1	May 15	June 1	Nov. 10
C. H. Miller	Antlers	" 26	" 5	" 20	" 1	" 20
H. T. Gravestock	Canon City	" 20	" 3	" 15	" 1	Oct. 31
C. H. Gravestock	"	" 20	" 3	" 15	May 31	Nov. 2
J. M. Mortimer	"	" 15	" 1	....	....	Oct. 29
Adam May	Debeque	" 15	" 1	" 15	June 1	Nov. 13
Martin Nelson	Greeley	" 24	" 5	" 20	" 10	Oct. 31
I. W. Clapper	Loveland	" 20	" 10	" 20	" 10	Nov. 10
F. Niemeyer	Evans	" 20	" 5	" 20	" 10	Oct. 24
D. G. Edgerton	Carbondale	" 20	" 10	" 20	" 10	Nov. 9
Arkansas Valley Substation	Rocky Ford	" 17	" 2	" 16	May 31	Oct. 21
Agricultural College	Fort Collins	" 18	" 10	" 26	....	" 21
Average	....	April 19	May 5	May 18	June 4	Nov. 4

RECORDS OF HARVESTING.

Name	Place	WEIGHT OF CROP IN TONS PER ACRE FOR EACH PLANTING.			
		First	Second	Third	Fourth
M. D. Parmenter	Lamar	39.9	30.2	33.6	27.8
C. H. Miller	Antlers	9.3	10.2	9.9	......
H. T. Gravestock	Canon City	23.5	24.7	12.2	12.6
C. H. Gravestock	"	11.8	17.5	10.9	10.2
J. M. Mortimer	"	27.7	13.6	Did not grow	
Adam May	Debeque	30.3	29.2	28.1	24.5
Martin Nelson	Greeley	27.0	23.8	10.9	9.5
I. W. Clapper	Loveland	27.2	17.0	8.7	5.6
F. Niemeyer	Evans	65.3	54.4	43.5	32.6
D. G. Edgerton	Carbondale	13.3	8.7	8.0	8.6
Arkansas Valley Substation	Rocky Ford	15.2	16.6	26.0	18.9
Agricultural College	Fort Collins	23.8	20.9	22.7	20.0
Average 12 trials	....	26.2	22.2	......	......
Average 10 trials	....	27.7	24.3	20.4	15.3

The results are surprisingly conclusive. They show in the strongest manner the advantage of early planting. And by early planting as used here is meant very early planting, much earlier than has heretofore been considered safe.

From the financial side no argument could be stronger in favor of early planting than these results. The planting of April averages 27.7 tons per acre, with a steady decrease to 15.3 tons for the first of June. It has usually been considered that from May 10 to May 20 was the best time to plant beets in Colorado. The difference between the first and third plantings is 7.3 tons per acre, which means a loss of $31.00 per acre by the late planting.

The results at Fort Collins show strikingly how much cold the sugar beet plant can stand and thrive. The first planting was made April 18. The ground was in fine moist condition from a heavy rain and the beets germinated at once. The nights were cold, i. e. below freezing, until April 24; then followed a week of warm weather with four frostless nights. The first week in May was cold and on May 4, the temperature fell to nine degrees below freezing. The beets were not at all injured by the cold and made the most nearly perfect stand and the largest crop of all the different plots grown on the farm that year.

Such a test as this is not complete until it is known whether or not the date of planting has influenced the quality of the beet either in sugar or purity.

Through the courtesy of the Division of Chemistry of the Department of Agriculture at Washington, most of the analyses of the beets were made by them. The beets were carefully wrapped in oiled paper and sent by mail. In several cases the beets were weighed before sending and then weighed in Washington before analyzing to determine the amount they had dried out. The loss was surprisingly small. The average was less than three per cent of shrinkage. The analyses are given as made on the samples as they were analyzed at Washington and are therefore this small amount, about one thirtieth, too high. We are indebted to the Colorado Sugar Co., of Grand Junction, Colorado for the analyses of nearly a hundred samples of beets grown on the College Farm at Fort Collins. In these cases the shrinkage in shipping the samples was very carefully noted and the analyses, as given later, are all corrected to indicate the condition of the beets when harvested.

RECORDS OF ANALYSES.

Name	Place	PLANTING. First: Sugar in beet	First: Purity	Second: Sugar in beet	Second: Purity	Third: Sugar in beet	Third: Purity	Fourth: Sugar in beet	Fourth: Purity
M. D. Parmenter	Lamar	11.2	75.7	14.0	79.9	10.5	71.9	13.1	76.7
C. H. Miller	Antlers	14.5	79.3	14.1	77.9	15.8	82.2	......	......
H. T. Gravestock	Canon City	17.5	84.0	20.3	88.4	19.6	86.9	20.5	90.8
C. H. Gravestock	"	19.4	88.3	18.6	89.1	19.5	90.3	17.1	85.3
J. M. Mortimer	"	16.3	84.3	17.9	85.1	......	......	......	......
Adam May	Debeque	12.4	76.5	14.3	82.9	13.6	77.7	13.6	78.6
Martin Nelson	Greeley	17.0	84.0	15.1	83.3	16.7	85.9	16.2	86.7
J. W. Clapper	Loveland	14.2	84.2	16.0	82.8	16.3	85.1	13.6	76.5
F. Niemeyer	Evans	13.8	81.0	14.2	83.7	14.3	78.9	16.6	85.8
D. G. Edgerton	Carbondale	14.7	83.3	15.1	85.0	15.2	86.5	14.1	84.1
Average	....	15.2	82.1	15.96	83.8	15.7	82.4	15.6	80.6

It will be noticed that there is scarcely any difference in the average analysis of the crops from the different plantings.

The second planting averages a trifle the best in both sugar and purity, but not anywhere near enough to offset the much larger yield of the earlier planting.

It can be said that taking into account all the factors of the problem there is a decided advantage in early planting; it gives a better stand, produces a larger crop and this crop is of good quality in sugar and purity.

For the sake of convenience in thinning the beets it is not advisable to plant all the crop at one time. The best way is to plant a third of the ground as early as possible, as early as one can be sure of water to irrigate up the seed if necessary and as soon as it seems warm enough to germinate the seed. Then put in the second third as soon as the first planting appears above the ground and the last within the next ten days.

2. DISTANCE BETWEEN ROWS.

Where sugar beets are raised by the natural rainfall it is customary to plant the rows as close together as it is possible to get a horse through them to cultivate. The present writer has seen a hundred acre field of beets in

Nebraska where the rows were but fourteen inches apart. Many experiments have shown that a sugar beet to do its best needs one square foot of ground. If then the rows could be made twelve inches apart and the beets thinned to twelve inches in the row we should have the largest possible crop per acre of the highest sugar and purity.

Where the beets are raised by irrigation the rows must be far enough apart to allow an irrigating furrow to be run between. It will not do to allow the water to run against the beet itself, because it injures the crown of the beet and lowers the sugar and purity. The water must be kept in the furrows and the sides of the furrow made high enough to carry the water over any small irregularities in the surface, the water soaking sideways through the ground to the beet. If the surface of the land was an absolute plane, a furrow three or four inches deep would be an abundance and such a furrow could be made in rows eighteen inches apart. In our tests on the College farm we have grown many fields of beets successfully in eighteen inch rows where the land was in the best possible condition. But where the land is not properly smoothed, an eighteen inch space in not enough to throw up a furrow high and deep enough to keep the water off the beets. Under most conditions, with gently sloping or nearly flat ground and long rows, twenty-four inches apart is none too much for ease in irrigating. The twenty-four inch row will not raise so large a crop per acre as the eighteen inch row.

A set of experiments was made to determine whether it is possible to get the benefit of the large space for furrowing and irrigating while at the same time obtaining as large a crop as would be gotten from rows close together. The rows were planted alternately eleven and twenty-seven inches apart. All the irrigating was done in the twenty-seven inch space, while the beets on the two sides of the eleven inch space were so near together that after the thinning and the first hoeing, they shaded this small space and it required no further attention. The two rows together occupied thirty-eight inches, an average of nineteen inches per row. These plots were planted side by side with those in which all the rows were twenty-four inches apart and which were irrigated between each row. This second method, and also the method of eighteen inch rows, require twice as many irrigating furrows as the twenty-seven and eleven inch furrows.

The results are given below.

DISTANCE BETWEEN ROWS.

Name	Place	WEIGHT, CROP, TONS PER ACRE. Rows 24 inches apart	Rows 27 and 11 inches apart
M. D. Parmenter	Lamar	30.9	40.8
C. H. Miller	Antlers	10.2	13.8
H. T. Gravestock	Canon City	25.1	26.4
C. H. Gravestock	"	14.2	14.3
J. M. Mortimer	"	13.6	24.8
Adam May	Debeque	27.6	35.8
Martin Nelson	Greeley	25.5	31.2
I. W. Clapper	Loveland	15.1	13.6
F. Niemeyer	Evans	54.2	66.0
D. G. Edgerton	Carbondale	9.8	13.2
Arkansas Valley Substation	Rocky Ford	16.8	17.8
Agricultural College	Fort Collins	19.8	22.1
Average		21.9	26.71

The results are strongly in favor of the twenty-seven and eleven inch rows. It is not claimed that this method will give a larger yield per acre than all eighteen inch rows, but it is believed that it will give just as large a yield and can be profitably used on ground where it would be very difficult to use the eighteen inch row. The twenty-seven inch row is so wide that it allows an abundance of space to put in a big furrowing plow, use a good head of water and run a given stream a long distance—in other words, do a good thorough job of irrigating.

3. IRRIGATING THE SEED.

This is the most troublesome problem before the Colorado sugar beet raiser at the present time. If all seasons were the same in the rainfall, the problem would soon be solved. The years 1894 and 1900 show the possible extremes in this matter. In 1894 wheat that was sown the fall before did not germinate until the ground was irrigated the last week in May, and yet, wheat requires much less moisture to germinate than beet seed. In 1900 the month of April was as wet out here in the arid region as it usually is along the Atlantic or Gulf coasts. The ground was too

wet to be worked, and the beets put in the first week of May made an absolutely perfect germination without irrigation.

The year 1899 may be considered a fairly normal year for the earlier plantings and rather dry for the later. The tests of irrigating up the seed were made about the first of May, when the conditions were not far from an average. The plots were all planted on ground that had not been irrigated, and then half of them were allowed to depend on rain for the water necessary to germinate the seed, while the other half was irrigated the same day the seed was planted.

The following table shows the results of the two methods:

IRRIGATING THE SEED.

Name	Place	WEIGHT, CROP, TONS PER ACRE.	
		Seed irrigated at planting	Seed not irrigated at planting
M. D. Parmenter	Lamar	35.3	36.5
C. H. Miller	Antlers	12.0	Did not grow
H. T. Gravestock	Canon City	27.8	23.7
C. H. Gravestock	"	16.3	12.2
J. M. Mortimer	"	19.2	Did not grow
Adam May	Debeque	32.6	30.7
Martin Nelson	Greeley	26.2	30.5
I. W. Clapper	Loveland	15.0	13.8
F. Niemeyer	Evans	59.9	59.0
D. G. Edgerton	Carbondale	11.2	11.8
Arkansas Valley Substation	Rocky Ford	17.8	16.9
Agricultural College	Fort Collins	22.3	19.6
Average		26.3	25.4

Although the general average is in favor of irrigating up the seed, the figures of the individual plots show some for and some against it. There seems a probability that no uniform rule will apply to the whole of Colorado, but it is safe to make this a rule. Prepare for irrigation at time of planting; if within five days after planting, the seed shows no signs of swelling and sprouting, turn on the water and keep the ground wet until the plants show a full stand.

4. VARIETY TESTS.

Four varieties of sugar beets were grown on the College

farm in 1899 and all four were grown both on a heavy clay soil and a clay loam. The records of the harvest and analysis are given below. The Zehringen and the Vilmorin No. 1, were sent by the Department of Agriculture at Washington, while the Vilmorin No. 2 and the Kleinwanzlebener were furnished by the Oxnard Sugar Co., of Norfolk, Nebraska.

All the samples were taken October 21.

VARIETY TESTS.

Variety	Crop per acre Tons	Total Solids	Sugar in juice	Purity
Heavy clay soil--				
Zehringen	22.2	18.74	14.55	77.5
Vilmorin No. 1	20.9	20.21	16.29	80.8
Vilmorin No. 2	20.4	18.69	15.03	80.2
Kleinwanzlebener	17.9	18.67	13.73	73.6
Clay loam—				
Zehringen	....	18.18	15.75	86.8
Vilmorin No. 1	....	17.55	14.33	81.7
Vilmorin No. 2	....	18.85	16.38	86.9
Kleinwanzlebener	....	17.61	14.07	79.9

Analyses were made of the beets from the different plots grown on the College farm in 1899 and are given below. The variety used in each case was the Zehringen sent by the Department of Agriculture at Washington.

Date of planting	Remarks	Crop per acre Tons	Total Solids	Sugar in juice	Purity
April 18	24 inch rows, not irrigated	23.8	18.59	14.86	78.0
May 4	" " " "	22.2	18.74	14.55	77.5
" 10	" " " "	20.9	17.86	14.74	82.6
" 10	" " " "	18.7	17.64	14.00	79.4
" 10	" " irrigated	20.9	17.74	14.28	84.4
" 10	27 and 11 inch rows, not irrigated	20 5	17.58	14.06	80.2
" 10	" " " irrigated	23.7	18.57	14.87	80.3
" 10	24 inch rows, seed soaked	24.5	17.57	13.75	78.2
" 10	" " half the seed soaked	27.5	17.96	14.19	80.1
" 26	" " not irrigated	15.3	16.18	12.62	78.0
" 26	" " irrigated	22.7	17.08	13.78	80.5

5. SUMMARY OF BEET TESTS, 1899.

Different dates of planting.

April 19	20.7 tons per acre
May 5	24.3 " " "
May 18	20.4 " " "
June 4	15.3 " " "

	Sugar in beet. Per Cent.	Purity. Per Cent.
April 19	15.2	82.1
May 5	15.9	83.8
May 18	15.7	82 4
June 4	15.6	80.6

Distance between rows.

24 inches	23.7 tons per acre
27 and 11 inches	28.1 " " "

Irrigating up the seed.

Irrigated, all grew	26.3 tons per acre
Not irrigated, two failed, the rest	25.4 " " "

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A Soil Study.

PART II.

The Crop Grown: SUGAR BEETS

—BY—

WILLIAM P. HEADDEN.

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* Elected July 2, 1900. Died July 12, 1900.

EXPERIMENT STATION PUBLICATIONS.

The publications of the Experiment Station are of four classes:

1. **BULLETINS.** These are distributed, as far as the editions permit, to those interested in Colorado agriculture. They comprise bulletins on irrigation matters, sugar beets, alfalfa, barley and other field crops, cattle and sheep feeding, strawberries and other small fruits, insects, etc.

2. **ANNUAL REPORTS.** These are largely administrative and technical, printed in small editions, and not ordinarily sent to individuals except on request.

3. **PRESS BULLETINS.** Shorter statements of experience in various lines, or information needing immediate distribution. Sent to papers and to individuals according to the subject matter.

4. **RIVER PRESS BULLETINS.** Weekly reports issued during the irrigation season, rendering information on the current water supply, obtained in pursuance of other investigations, available for the public. Issued in small editions, and sent to newspapers and individuals in Northern Colorado.

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30.	Notes on Tomatoes	W. W. Cooke
31.	The Hemiptera of Colorado.	C. P. Gillette
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58.	A Soil Study. Part 2. Sugar Beets	W. P. Headden

PRESS BULLETINS.

1. The Sugar Beet Caterpillar.
2. Colorado Sunshine.
3. The Beet Army Worm.
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A Soil Study:

Part II.* The Crop Grown: SUGAR BEETS.

By WILLIAM P. HEADDEN, A. M., Ph. D.

INTRODUCTORY.

PREVIOUS WORK OF THE STATION ON SUGAR BEETS.

§ 1. This Station has already published nine bulletins on the subject of sugar beets, seven of which have been devoted to the demonstration of the fact that remunerative crops of sugar beets can be grown in the irrigated sections of this State up to altitudes of 7,800 feet. The earliest experiments recorded, 1888, show a trifle over 12 per cent. of sugar as the maximum per cent. present in any of the varieties experimented with. The only object aimed at in the experiments of that year seems to have been to determine whether the beet could be successfully cultivated under our conditions. The results were most encouraging, both in regard to the percentage of sugar present in the beets and also the tonnage, which ranged from 24 to 30 tons per acre. This yield was estimated from the product of an average row 450 feet long.

§ 2. The experiment of 1888 was not continued in 1889, but another line of work was undertaken, namely, to study the effect of various soils upon the composition of the ash, the percentage of the sugar, and on the feeding value of the beets. The results of this investigation were published in 1890 as Bulletin 11.

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* Part I., forming Bulletin 46 and issued in 1898, is out of print. Most of the reports of the Station have something about sugar beets. Of the bulletins treating of sugar beets, none but 36, 51 and 57 can be supplied, except to libraries. Those printed are as follows:

7. Potatoes and Sugar Beets. April, 1889. Profs. Cassidy and O'Brine.
11. Sugar Beets. April, 1890. Director Ingersoll and Dr. O'Brine.
14. Progress Bulletin on Sugar Beets. January, 1891. Dr. O'Brine.
21. Sugar Beets; Potatoes; Fruit Raising. October, 1892. F. L. Watrous.
36. Sugar Beets. March, 1897. Prof. Cooke and Dr. Headden.
42. Sugar Beets in Colorado in 1897. February, 1898. Prof. Cooke and Dr. Headden.
46. A Soil Study. Part I. The Crop Grown: Sugar Beets. June, 1898. Dr. Headden.
51. Sugar Beets in Colorado in 1898. March, 1899. Prof. Cooke.
57. Farm Notes. Alfalfa; Corn; Potatoes; Sugar Beets July, 1900. Prof. Cooke.
58. A Soil Study. Part II. The Crop Grown: Sugar Beets. August, 1900. Dr. Headden.

§ 3. During the season of 1890, Pres. Ingersoll, who was the Director of the Station, and Dr. O'Brine, Professor of Chemistry, joined in a study of the general condition and outlook for the beet sugar industry; while the Horticultural and Chemical Departments cooperated in further study of the sugar beet. The specific subjects with which they experimented during this season being a study of the effect of the distance between the beets in the row upon the amount of sugar contained in the beets, and of the relation between the size of the beet and its sugar content.

§ 4. A number of persons had, by this time, become sufficiently interested in the subject to grow sugar beets and send them to the Station for analysis. The descriptions of the samples, as received at the laboratory, were very imperfect, as was to be expected, but the results obtained fully justified the conclusion of Bulletin 14, which I can do no better than to quote:

> We believe that it has been established that the soil and climate of Colorado are favorable to the production of sugar beets, and that they can be successfully and profitably raised to the advantage, both of the farmer and manufacturer.

§ 5. Experiments were continued during the years 1891 and 1892, not only by the Station at Fort Collins, but also at the Substations in the San Luis Valley, Arkansas Valley and the Divide, also by individuals in the Arkansas Valley and in the neighborhood of Fort Collins. The chief importance seems to have been attached to the endeavor to determine how much irrigation is required to produce the best results, and to notice the effects of both too little and too much irrigation upon the crop, and the percentage of sugar in the beet. The effect of the distance between the beets in the row was also studied, but was subordinated to the questions of irrigation and cultivation. The results obtained at the Arkansas Valley Substation at Rocky Ford during these years, 1890 to 1892, were published in Bulletin 21, October, 1892. The rest of the results were not published until March, 1897, in Bulletin 36, which contains a succinct statement of the results recorded up to that date; some of which, about one third, had not been published in any previous bulletin.

§ 6. In the spring of 1897 the public seemed sufficiently interested to justify the Station in again taking up the subject, and having received quantities of seed from the Department of Agriculture at Washington, and also from other sources, it was distributed to persons in different sections of the State, together with explicit instructions how to plant, to cultivate, and especially how to harvest the samples for analysis. The results obtained were, more satisfactory data concerning the time of planting, cultivation and harvesting of the crop. In addition to this, experiments were made at a greatly increased number of localities throughout the State. In

other words, the experiments were greatly multiplied and made simultaneously. So far as quantity and quality of crop was concerned, we only corroborated the results of previous years, *i. e.*, that the soils of Colorado produce beet crops which compare favorably with those produced elsewhere, where the beet sugar industry has proved a profitable venture. There was added to this the results of a study of the conditions at and around the beet sugar factories of Nebraska, Utah and New Mexico, making the statement of facts concerning this industry as complete as possible, and giving the public the fullest possible data wherefrom to draw their own conclusions as to the advisability of engaging in this industry.

§ 7. At this time, the season of 1897, the Department of Chemistry began an independent investigation, whose principal object was a study of the chemistry of the crop as affected by an alkalized condition of the soil. This work traversed a number of questions pertaining to the crop in a fuller and more systematic manner than had previously been done. The sugar in the beets was determined weekly, beginning September 2, and continued until October 13, when the crop was harvested; and from time to time till January 8, 1898, in beets left in the ground and covered with straw to protect them against severe freezing. This gave us data respecting the effect of alkali upon the amount of sugar present and its effect upon the time of maturing; the composition of the ash at various periods of growth, the distribution of both sugar and ash constituents in the beet, the composition of the beets and leaves in regard to their feeding value, the total dry matter in the leaves and roots, its quantity in the respective thirds of the latter, etc. The results of this year's work are contained in Bulletin 46. In 1897 the Station carried on two lines of experimentation with sugar beets, one economic and the other almost purely chemical, resolving itself into a soil study, which it was intended to be.

The work was continued in 1898 and 1899. Some of the results of 1898 have already appeared as Bulletin 51. This consists of more extended experiments upon the effects of the date of planting, methods of planting, time of thinning, distance between plants in the row, experiments with varieties, and a comparison of home grown and imported seed in regard to the quality of the beets produced.

§ 8. The following pages record the further observations made during the years 1898 and 1899, being, in fact, a continuation of Bulletin 46, and for that reason a few of the conclusions of that bulletin are reproduced here:

The effect of the alkali, present in our soil, upon the sugar content of the beet is not, of itself, detrimental.

The maturing, or ripening, of the crop corresponds to an increase of from 2 to 3.5 per cent. of sugar in the beet, and about one third of the total yield of sugar.

The rate of drying out of beets is about 5 per cent. for the first 24 hours, but by the end of five days it falls to about 2 per cent. and remains practically constant for the next twelve days.

The weight of the leaves of Colorado grown beets equals about 87 per cent. of the weight of the roots. The weight of the leaves does not increase materially during the last six weeks of the growing season, but during this time the weight of the root increases by 64 per cent. of its weight at the beginning of the period, or 39 per cent. of the weight of the mature beet.

The presence of alkali increases the weight of the leaves very slightly, but has no marked influence on the date of maturing.

As the sugar is formed there is a disappearance of dry matter, other than sugar, in the beet, suggesting the formation of the sugar in the root by the transformation of substances already deposited therein.

The effect of alkali upon the percentage of ash in the roots is to increase it by about 2 per cent., reckoned on the dry matter.

The composition of the ash of the beets seems not to have been affected by the different character of the soils experimented with, either because there was so great an abundance of available, and to the plant, acceptable, mineral matter present that it was not affected by the presence of a large quantity of other salts, or the composition of the ash of the sugar beet is very constant. I think that the latter is the case. The composition of the ash is represented by the following approximate percentages: Sulphuric acid, 3.5; phosphoric acid, 7–9; alkalies, 48–52; lime, 2–3; magnesia, 6; chlorin, 11.50–14.50; carbon dioxid, about 15.

The ash of the beet leaf has a general composition which, like that of the beet, is the same throughout the season, except that there is an increase in the chlorin as the plant approaches maturity.

§ 9. The trials in different parts of the State in 1897 aroused sufficient interest in the possibilities of the sugar industry in Colorado, for the resources of the Station to be supplemented by aid from the United States Department of Agriculture, from the Chamber of Commerce of Denver, and from various counties in the State. This aid was largely given through the solicitation of the Chamber of Commerce, and was principally in form of prizes to induce growers to compete for good results. The field trials were directed by Prof. W. W. Cooke. Over 800 analyses were made by the Station. The results of these tests, together with the study of the best methods of growing sugar beets, is given in Bulletin 51.

§ 10. Some additional tests on methods of cultivation, dates of planting, distance between rows, and irrigating the seed are given in Farm Notes, Bulletin 57, by Prof. W. W. Cooke. These are the results of cooperative trials with growers in different parts of the State. The same bulletin reported the results of the tests made throughout the State in cooperation with the Department of Agriculture and the Chamber of Commerce.

THE CHEMICAL WORK OF 1898 AND 1899.

DESCRIPTION OF THE CONDITIONS.

§ 11. The plot on which the beets were grown in 1898 was the same as that used in 1897. The character of this plot having been fully described in Bulletin 46, p. 5, it will not be repeated in this place. The cultivation of the preceding season and the effects of the soil remaining thrown up in ridges over winter, exposing it to the weathering action of the season, tended to better its mechanical condition. This was, as I stated in Bulletin 46, the result most desired in order to reduce our study to the question of the effect of the alkali upon the crop. In addition to the weathering, effected as above stated, I endeavored to further modify the mechanical condition by the application of manure and straw. The plot was divided into sections one hundred feet long and twenty-five feet wide; alternate sections received an application of manure at the rate of sixty-four tons to the acre, and one section of the plot, the most difficult one to handle, received a dressing of cut straw at the rate of fourteen tons to the acre.

My object was twofold: First, to study the effect of the manure upon the soil; second, to observe its effect upon the crop.

The straw was used that we might be able to judge, in a measure at least, of the relative effect of the manure as a mechanical agent and as a fertilizer. The crop raised was, as in 1897, sugar beets, and we were successful in getting the same varieties, but the seeds were from different lots, for the crop of 1898.

The cultivation was similar to that received by the preceding crop, but having gotten rid of a patch of poverty weed on the south side of the plot, we were not troubled by insects to nearly the same extent as during 1897, still both of the beetles, *Systena taeniata* and *Monoxia puncticollis,* observed then, appeared again and did some damage. We, however, did not have recourse to the use of insecticides as in the preceding year. In our case we found that removing the poverty weed and keeping our crop well tilled sufficed to keep the beetles down to such an extent that the damage done by them was not serious.

The alkali appeared nearly as bad as heretofore, and we had trouble with the same sections that had previously given us trouble.

The corroding effects of the alkali was observed, but not to the same extent, and the spots of ground showing it were not so large as in 1897. There was a small spot in which but few seeds germinated; there seemed to be an abundance of moisture, the seed were found at a depth of an inch and a half, and the mechanical condition of the soil was good. This failure of the seed to germinate, for they did not come up at any time during the season, remains unexplained. It was observed that some beets in this part of the patch continued to come up for weeks after the first had made their appearance, especially after irrigation. It is very improbable that this was due to lack of moisture, for this was observed in a very wet portion of the patch, but not the wettest, nor indeed is it more strongly alkalized than some other parts of the plot. The analyses of the soils taken from these spots, and those of the ground waters also, show a larger amount of magnesia present than in other places within the plot; this is more markedly the case with the ground waters than with the soils. Experiments show that magnesic sulfate retards the germination of seeds, but neither the soil nor the ground water, nor yet the water-soluble portion of the soil, shows a sufficient quantity of magnesic sulfate to account for this. The inorganic substances present do not suggest any solution for the failure of the seed to come up.

THE WATER CONDITIONS.

§ 12. The ground was very wet in the spring, so much so that it caused a delay of two weeks or more in planting. The crop was not planted till June 4; some of it not till June 13. This, however, was not due to the condition of the soil. The only irrigation that we were able to give this crop was given from July 8 to 10, and this was with seepage water, of which we had only a scant supply, so scant that we could not obtain any sample of off-flowing water. But a few days later, a heavy rain having fallen in the mountains to the west of us, more than doubling the flow of the river, a large quantity of water was turned into the Larimer County Ditch No. 2 and its laterals. One of our dams was washed out and the lower portion of our beet plot flooded. This happened between the afternoon of the 13th and the morning of the 14th of July. The drains for receiving the off-flow water were immediately opened and the water turned out of the ditch. Samples of both on and off-flow water were taken. The patch drained rapidly, the surplus water being removed in about three hours. This was the only irrigation that the crop received. The total rainfall for the months of July, August, September and October was 2.8 inches. The total amount of water received by the crop, from the time of planting till harvested, was about eight inches. The ground was wet at the time of planting and the water plane was within less than two feet of the surface.

The level of the ground water fell about a foot in the next 30 days. The irrigation given from the 8th to the 11th was not sufficient to raise the level of the ground water quite as high as it was at the time of planting and it then fell rapidly, making a fall of almost exactly two feet in eleven days. This fall represents the rate of drainage and evaporation. The weather was hot and evaporation was rapid, but that drainage was active can scarcely be questioned. Especially so because the water level in the adjoining, and lower lying, land had not been raised and there was only our small and local supply of water to be removed.

The water level, at a point about two hundred feet to the east of my plot, was not at any time sensibly effected by the irrigation of my plot. The well, the measurements of which form the basis of this assertion, is not very far from an underdrain, perhaps 75 feet from it, but I do not think this fact has very much, if anything, to do with our failure to perceive any change in the level of the water in this well. I think it more likely that the amount of water used was simply insufficient to force its way so far through the soil.

§ 13. This is not the place I intended to discuss the question of water, further than to state the supply furnished to the crop, but it was observed that the different wells fell at very different rates. I have given the maximum fall for the eleven days immediately succeeding the 14th inst. From this date on the water plane fell slowly until it reached its greatest depth for the season during the first week of October. But during the next fourteen days it rose a foot, in some of the wells rather more.

§ 14. The water level at the lower end of the plot ranged, from the end of July to October 10, from 3 to 4.5 feet below the surface, and there were but few beets in this section, as was repeatedly noted in Bulletin 46, but at the western, or higher end, the water level was from 5.2 feet to 6 feet below the surface, and the crop was excellent. At an intermediate point we have the water level ranging, during this same period, from 3.5 to 4.5 feet, with an abundance of alkali and yielding a good crop. With a part of the facts before us it would be easy to justify the inference that beets will not grow where the water plane is from 3 to 4.5 below the surface, but in view of other facts, observed at the same time, we hesitate to offer any statement relative to the cause of the failure of the crop to grow in the section in question, either in regard to the alkali or the water.

§ 15. Notwithstanding the nearness of the water to the surface of the ground, the crop showed the need of water throughout the latter part of the season; our field notes showing that on July 22 the beets were wilted and the water plane low. The weather

was hot and the wilting may have been dependent upon this as much as upon a lack of water in the soil, but on August 13, it is remarked that the crop needs water and on the 17th the condition of the ground is designated as dry, though we had had in the meantime, August 4 and 5, a rain fall of 0.78 inch. The ground had been kept as mellow as possible and free from weeds, having received, in all, five cultivatings and five hoeings.

§ 16. There was no need of irrigating the plot during the season of 1899, though we gave it a thorough soaking from August 31 to September 2, not because the crop needed it, but for the purpose of puddling the ground and of studying the changes which took place in the water by its contact with the soil.

§ 17. The chief cause of our abundance of water was the fact that we received a sub-irrigation July 1 to 7, coming from the western part of the farm. There is a drain immediately west of my plot which should have taken off the greater part of this underflow, but it did not prevent my plot being filled nearly to the surface with water. The water plane being raised to within 18 inches of the surface, as was proven, not only by the water in the wells, but also by several holes dug in order to verify this observation. This development was something entirely new. I knew that the stratum of gravel underlying the plot was filled with water and that there was probably a flow to the eastward through it. I thought that it came from a more distant source, believing that we were fully protected against sub-irrigation of this sort by a ditch constructed to utilize the seepage water gathered for a mile or more to the westward of us, and further, by the drain alluded to. I believe that these two really gather all the water that, under ordinary conditions, drains from the higher land to the westward of us, but in this instance an unusual supply of water enabled the Farm Department to run water night and day for a week, with the result that the water found its way down into and filled up my lower lying land. The wetness of the land interfered with the cultivation of the crop, but the mechanical condition of the soil was greatly improved over that of the preceding seasons, so that the cultivation was much easier than in 1897 and '98.

§ 18. The ground was not disturbed after the irrigation of September 2, but it was allowed to bake and harden as much as it would. This crop was cultivated twice, hoed twice and irrigated once.

In 1898 the crop was irrigated but once, because we could not get water to irrigate with. This single irrigation was only a light one, applied July 8 to 10, and a part by accident on July 14. Subsequently the ground became very hard, in spite of our efforts to keep it mellow. In 1899 we sought to pack and allow it to be-

come hard and dry after the irrigation of September 2. The crop, taking the whole patch, was in 1898, 13 tons to the acre, and in 1899, 14.5 tons. I attribute the increased crops to the improvement in the condition of the soil and to a rather better stand, without considering whether this latter was due to the improved condition of soil or not.

THE EFFECT OF THE MANURE UPON THE STAND AND THE BEETS.

§ 19. The effect of the manure was very marked, improving the stand by at least 10 per cent. I believe that under ordinary conditions the effect of so heavy a dressing of manure would not be followed by an improvement in the stand, but in our case it was; the weather conditions turning favorable just after the planting.

The planting took place on May 11, followed by a rainfall of over 1.5 inches during the rest of the month, which was well distributed, rain falling on twelve of the remaining twenty days of the month. Had this not been the case, it is a question whether the manure might not have facilitated the drying out of the soil sufficiently to more than offset its stimulating effect upon the germination of the seed. As it was, the seed germinated better, the plants were more vigorous throughout the season, and the weight of the crop was greater; but the shape of the beets was inferior, very many of them being rooty, forming a chunky beet with a number of roots spreading out from it, literally covered with masses of fibrous roots. The ratio of tops to roots was not determined, but it was evidently higher than where no manure was used. The six plots used for manuring agreed fully in justifying the above statements. There is no reason to suppose that other conditions would have modified any of these results, except the one already mentioned as possibly exceptional, *i. e.*, that manuring improved the germination and stand. Our observations on the effect of coarse manure, under our conditions, leads to this doubt, which we would not otherwise entertain.

EFFECT OF THE MANURE AND ALKALI ON THE SUGAR IN THE CROP.

§ 20. In 1897 we found that the ripening of our crop, or better, that the formation of the sugar, was much more rapid between October 6 and 13, than at any other period during the season, either before or subsequent to this date. Our results showed that about one third of the sugar contained in the crop made its appearance during these seven days. As the crop of 1898 was later than that of 1897, both in planting and maturing, we did not attempt to follow the development of the sugar throughout the season, but contented ourselves with endeavoring to determine the effects of our alkali and manure upon the date and amount of sugar produced during the period of this maturing process. Our first samples were

accordingly taken on October 3. These were trial samples taken to help us in judging of the condition of the crop. We had already received a number of samples from the Farm Department, but these varied greatly, and we did not know from which of the different plots the sample had been taken. It was, furthermore, out of the question for us to take the plot most nearly representing the plot taken for comparison in 1897, for this plot had been hastened into ripening by lack of moisture. This was so pronounced, at this date, that the tops wilted to the extent of lying flat on the ground. The soil was dry to a greater depth than that reached in digging the beets. If there had been no other differences, these facts make it evident that we cannot compare these plots, so I shall use another whose history is as follows: In 1891 it received a dressing of manure, was planted to potatoes; 1892, trucked, not manured; 1893, fallow; 1894, rye, crop cut green and removed from plot; 1895–'96–'97, fallow; 1898, planted to beets but not manured. The varieties grown on this plot were Vilmorin Improved, White Imperial, White French and Dippe's Improved Kleinwanzlebener.

§ 21. In the following table we do not see the pronounced increase in the amount of sugar as the season advanced or the crop matured, as shown in the crop of 1897, but the season was very different. In 1897 we had, in the early part of September, enough rain, 0.74 of an inch, to stimulate the beets into an increased growth, after a period of comparative inactivity. This produced a material increase in the weight of the crop, but the relative quantity of sugar was less than before this period. The effect was noticeable for two and a half weeks or more, at the end of which period the sugar had increased again and reached its maximum for the season. In 1898 we had no such an abundance of water as in 1897. We were unable to irrigate more than once, and then far less copiously than in 1897, and the rainfall from August 6 to October 15, a period of 70 days, amounted to only 0.74 of an inch, which is the same amount that fell in four days, September 10 to 14, in 1897. The crop of 1898 received its moisture from the soil, developed continuously under very uniform conditions, and matured without showing a so uniformly large gain at the maturing period. In 1897 this amounted to from 2 to 3.5 per cent.; in 1898 the greatest gain for this period was 1.44 per cent. in two weeks. This observation is true in regard to the Farm plot as well as for our own. Furthermore, it is observable in the records of the Department that there is no such great increase in the percentage of sugar just at the time of ripening, unless the beets were already mature at the time of taking the first samples, which was not indicated by the deportment of the beets when grated, as the earlier samples became very black on being exposed to the air. The Department received a sample harvested September 27, 1898, original Kleinwanzlebener, which

TABLE I.—EFFECT OF MANURE ON SUGAR, DIFFERENT DATES AND VARIETIES, 1898.

DATE	Number.	(M) Manured. (N) Not manured.	Kleinwanzlebener.		Vilmorin.		Lion Brand.		Sugar.		Imperial.		Dippe's Kleinwanzlebener.		Vilmorin Improved.		White Imperial.		Average of all Varieties.	
			Percentage of Sugar.	Purity.	Percentage of Sugar.	Purity.	Percentage of Sugar.	Purity.	Percentage of Sugar.	Purity.	Percentage of Sugar.	Purity.	Percentage of Sugar.	Purity.	Percentage of Sugar.	Purity.	Percentage of Sugar.	Purity.	Percentage of Sugar.	Purity.
October 3	....	M	11.40	73.5	11.12	72 8	12.73	76.5	11.07	74.3	9.50	65.8	....	.....	....	.....	....	.....	....	.....
		N	11.83	75.3	13.30	77.3	14.63	80.2	14.49	82.4	13.16	79.6	....	.....	....	.....	....	.....	....	.....
October 8	1	M	12.83	79.8	13.53	80.9	15.44	82.4	13.73	79.5	12.92	77.6	....	.....	....	.....	....	.....	....	.....
	1	N	13.78	78.7	13.78	78.7	14.58	80.8	13.30	80.0	13.49	78.0	....	.....	....	.....	....	.....	....	.....
	2	M	13 40	83.4	11.80	77.1	13.07	76.0	10.64	73.8	13.26	76.3	....	.....	....	.....	....	.....	....	.....
	2	N	13.30	76.6	14.49	81.1	13.88	77.5	14.49	84.3	12.40	74.8	....	.....	....	.....	....	.....	....	.....
	3	M	12.35	78.9	11.82	78.4	13.21	78.0	11.53	76.2	11.97	74.3	....	.....	....	.....	....	.....	....	.....
	3	N	11.16	75.0	11.88	79.0	13.97	78.4	12.45	76.8	13.54	75.6	....	.....	....	.....	....	.....	....	.....
Average	....	M	12.89	80.7	12 45	78.8	13.90	78 8	11.97	76.5	12.71	76.1	....	.....	....	.....	....	.....	12.79	78.1
	....	N	12.75	76.8	13.38	79.6	13.81	78.9	13.41	80.4	13.14	76.1	....	.....	....	.....	....	.....	13.30	78.4
October 11	....	....	....	.....	....	.....	....	.....	....	.....	....	.....	14.75	82.9	13.78	80.0	11 40	71.4	....	.....
October 15	1	M	13.06	78.9	13.30	81.8	15.33	82.7	14.25	83.2	11.69	74.0	....	.....	....	.....	....	.....	....	.....
	1	N	9.74	70.6	13.06	79.0	16.86	86.5	13.72	82.0	13.63	79.2	....	.....	....	.....	....	.....	....	.....
	2	M	12.11	74.9	12.11	76.2	13.06	74.9	10.93	74.4	13.63	81.7	....	.....	....	.....	....	.....	....	.....
	2	N	13.73	80.7	14.49	81.3	13.78	81.7	13.78	81.2	14.49	80.6	....	.....	....	.....	....	.....	....	.....
	3	M	13.82	84.7	13.49	85.4	13.82	82.5	12.11	76.7	12.26	77.6	....	.....	....	.....	....	.....	....	.....
	3	N	10.93	76.5	13.16	80.4	13.54	78.2	12.11	78.1	13.97	80.2	....	.....	....	.....	....	.....	....	.....
Average	....	M	12.99	79.5	12.97	81.1	14.10	80.0	12.43	78.1	12.53	77.7	....	.....	....	.....	....	.....	13.00	79.3
	....	N	11.47	75.5	13.57	80.3	14.72	82.1	13.20	80.4	14.03	80.0	....	.....	....	.....	....	.....	13.40	79.6
October 18	....	....	....	.....	....	.....	....	.....	....	.....	....	.....	14.75	81.0	14.25	82.7	11.59	74.0	....	.....
October 22	1	M	13.06	79.2	12.97	81.4	15.20	83.9	14.49	87.3	13.52	81.2	....	.....	....	.....	....	.....	....	.....
	1	N	12.83	84.1	13.52	79.8	16.67	90.3	14.11	80.4	14 92	87.4	....	.....	....	.....	....	.....	....	.....
	2	M	13.61	86.5	11.40	78.5	12.97	79.0	12.97	86.5	13.06	80.9	....	.....	....	.....	....	.....	....	.....
	2	N	17.10	92.4	15.20	92.2	15.68	88.8	13.06	82.9	13.78	88.0	....	.....	....	.....	....	.....	....	.....
	3	M	12.83	78.1	11.40	77.7	12.45	73.1	10.60	68.1	13.30	80.2	....	.....	....	.....	....	.....	....	.....
	3	N	11.97	77.4	12.73	80.8	13.40	75.2	12 59	76.3	15.30	85.4	....	.....	....	.....	....	.....	....	.....
Average	....	M	13.17	84.6	11.93	79.2	13.54	78.7	12.69	80.9	13 29	80 8	....	.....	....	.....	....	.....	12.92	80.8
	...	N	13.97	84.6	13.81	84.3	15.25	84.8	13.25	78.9	14.67	86.8	....	.....	....	.....	....	.....	14.18	83.9
October 25.	2	M	12.83	75.7	....	.....	....	.....	....	.....	....	.....	....	.....	....	.....	....	.....	....	.....
	2	N	15.20	87.1	....	.....	....	.....	....	.....	....	.....	....	.....	....	.....	....	.....	....	.....
November 1	....	....	....	.....	15.39	85.4	14.82	81.0	12.59	77.6	15.34	81.7	15.77	77.1	13.97	79.2	11.88	70.9	14.67	82.6

contained 15.23 per cent. of sugar; a sample of the same variety, harvested November 2, contained 15.12 per cent. of sugar. These samples, harvested thirty-five days apart, show almost exactly the same percentage of sugar, and the coefficient of purity is also quite the same, *i. e.*, 83 and 81.

§ 22. The varieties grown by the Farm Department remained almost constant from October 3 to October 22, only one of the three varieties showing any material gain, and in this case a gain of only one per cent. I infer that this difference in the deportment of the crops of the two years was due entirely to the season, and not to either the cultivation or to the soils. There are three different soils and nine varieties of beets included in this comparison; five of the varieties of beets were grown on our alkali soil and the four others on two different soils. Our soil caused no deviation in this respect, and the conclusion of the preceding years, *i. e.*, that the alkalized condition of our soil produces no effect upon the development of the beet, is corroborated. The statement, however, that the maturing of the beet represents an increase, that is, a sudden increase, amounting to from 2 to 3.5 per cent., now seems to be an extreme variation. The following table showing the results obtained during the season of 1899 strengthen this view; the greatest increase being 1.1 per cent. from October 10 to 24, and we find no further change, though the experiments were continued until November 10:

TABLE II.—SUGAR IN THE MANURED AND NOT MANURED CROPS OF 1899.

DATE.	Number of Section.	(M) Manured. (N) Not Manured.	Kleinwanzlebener. Percentage of Sugar in Beets.	Kleinwanzlebener. Purity.	Kleinwanzlebener. Number of Beets in Sample.	Kleinwanzlebener. Average Weight of Beets. Grams.	Zehringen. Percentage of Sugar in Beets.	Zehringen. Purity.	Zehringen. Number of Beets in Sample.	Zehringen. Average Weight of Beets. Grams.
October 10	1	M	15.10	79.4	12	627.2	14.25	79.8	13	760.0
	1	N	16.34	82.4	12	661.5	14.06	79.6	11	688.1
	2	M	15.01	82.9	14	517.0	12.83	72.1	12	680.4
	2	N	16.34	81.5	12	491.4	16.06	81.3	12	456.2
	3	M	11.88	74.5	14	488.0	11.97	73.4	12	712.3
	3	N	13.97	82.0	12	846.0	14.92	83.8	12	610.0
Average	....	M	13.99	78.9	......	540.0	13.01	75.1	......	714.0
	....	N	15.55	81.9	......	666.3	15.01	81.6	......	585.0
October 18	1, 2, 3	M	13.20	77.7	29	666.6	12.83	71.1	18	710.5
	1, 2, 3	N	14.54	78.8	18	645.5	15.10	80.1	12	583.5
October 24	1	M	15.44	84.6	12	532.6	15.72	81.7	12	572.3
	1	N	15.58	82.3	12	615.8	17.57	89.1	12	496.7
	2	M	15.96	83 7	12	473.1	13.92	78.0	12	646.4
	2	N	15.58	81.9	12	587.2	16.34	84.2	12	527.4
	3	M	13.77	76 8	12	588.2	12.82	73.3	12	834.6
	3	N	14.87	78.3	12	728.3	15.82	80.2	12	538.6
Average	....	M	15.06	81.7	......	531.3	14.15	77.7	......	683.3
	....	N	15.34	80.8	......	643.8	16.24	84.5	.....	517.6
October 27	1, 2, 3	N	14.06	77.2	30	676.1	14.81	78.7	30	509.8
November 10	1, 2, 3	N	15.77	82.0	15	629.2	15.86	84.2	15	543.5

§ 23. The results of 1897, given on p. 13, Bulletin 46, and those of 1898 and 1899, given in the two preceding tables, but more especially the results of 1897 and 1898, because these are compared with beets grown on ground free from alkali and in good tilth, leave no doubt about the effect of alkali upon the quantity of sugar developed in beets grown on soils abounding in these salts; *i. e.*, they are not detrimental so far as the sugar and the coefficient of purity are concerned, nor does it effect the time of maturing.

THE EFFECT OF THE MANURE.

§ 24. It is usually stated and generally accepted that land on which a crop of beets is to be grown should not receive a dressing of manure immediately before being planted, but that it should receive the manure and be planted to some other crop between the manuring and the planting to beets. As already stated, I manured my plot heavily, 64 tons to the acre, in February, plowed it under in May and planted it to beets. The primary object was to observe its effects on the soil, but it presents an excellent example of the effects of manure upon the crop. I have already mentioned the fact that its effect upon the stand and growth of the crop was evident, and the tables show its effect upon the percentage of sugar and the coefficient of purity. The average for the fifteen samples taken from manured plots on October 3, 1898, is 12.79 per cent. sugar in the beets, with a coefficient of 78.1; the average for the corresponding set from the unmanured plots is 13.30 per cent. sugar in beets, with a coefficient of 78.4; for the samples taken October 15 the averages are: 13.00 per cent. sugar, 79.3 purity, and 13.40 per cent. sugar, 79.6 purity; for October 22 we found 12.92 per cent. sugar, 80.8 purity, and 14.18 per cent. sugar and 83.9 purity. The averages are in harmony with our statement that manuring land immediately before raising a crop of sugar beets on it tends to lower both the sugar content and the coefficient of purity; but its range is only from 0.5 to 1.2 per cent. sugar and from 0.1 to 3.1 in purity, provided we attribute the whole of these differences to the effect of the manure.

§ 25. The effect upon the form of the beets was in our case a much more serious consideration than the diminution of the sugar content and the coefficient of purity. The form of the beets was decidedly objectionable. The bad tilth of the ground of itself tended to the production of ill shaped beets, but the manure made them very rooty, giving rise to a short, chunky beet with several spreading roots and a large mass of fibrous roots. This was very noticeable and common to all of the varieties, but shown in different degrees.

§ 26. The crop of 1899 shows the same results, but the manure, having become more fully incorporated with the soil, effected the form of the beets less than in the preceding year. The percentage of sugar and the coefficient of purity were effected quite as pronouncedly as in 1898. This is evident from the tabular statement of the results for 1899, from which it appears that the manure caused a depression of as much as 2.3 per cent. (See Zehringen, samples taken October 18.) The effects of the manure upon the stand, color of the tops and development of the crop, were almost as

evident in '99 as they were in '98. The residual value of the manure, judging by its effects upon the second crop, is greater than one would be justified in anticipating. This is largely due, without doubt, to the peculiar resistance to complete decay and humifaction shown by manures in our soils. It is an often observed fact that manure when applied to a tilled crop remains a long time in the soil without undergoing that disintegration which we are accustomed to see in Eastern soils, where there is an abundance of rain and cloudiness prevails for a much larger percentage of the time than with us. This fact was not new to me, but I was of the opinion that the soil, with the water level within from 4.5 to 3 feet of the surface, would remain moist enough, especially when shaded by the tops of the beets, to cause the complete rotting of the manure early in the season, but it was not so. The manure, some of it scarcely decomposed at all, was abundant when the beets were plowed out and can at the present time, two years subsequent to its application, be easily recognized as distinct from the soil. The practical recognition of this is the wasteful custom, still too general, of making no effort to convert the straw and other litter of the farm into manure, or of using the manure to fill mud holes in the roads or dumping it on the commons when it has become necessary to remove it from the neighborhood of the houses. It is a question with the ranchman how to treat the manure so as to get good results without materially adding to the labor of irrigation. This is especially true of cultivated crops. The beets did not produce shade enough to effect, even with the aid of the moisture in the soil, the rotting of the manure.

§ 27. The straw with which we dressed one section did not withstand decay so persistently as the manure. This may be explained by the fact that there was less of it, by its being loose, without any matting together, and by its having been more uniformly mixed with the soil.

§ 28. The effect of the straw upon the sugar content and coefficient of purity is not pronounced, but it is certainly less prejudicial than that of the manure. I cannot say that I observed any effect upon the form of the beets which I could attribute to the direct action of the straw. But its ameliorating effect upon the soil was quite as pronounced as that of the manure.

This is in harmony with the view expressed in Bulletin 46, *i. e.*, that the soil experimented with is so rich in plant food that the effect, if any, of the alkali upon the growth and composition of the crop is obscured, and that it is not the chemical composition but the mechanical condition of the soil which is the factor of greater importance in any endeavor to improve its condition. This statement would be of little importance did it not apply to all of

the alkali soils that I have seen in this State, which I firmly believe that it does.

§ 29. The numbers of the sections 1, 2 and 3 in the tables have the same signification as in Bulletin 46. Section 3 is described as in very bad condition and low, very wet and alkalized to such an extent that the surface becomes coated to the thickness of from one quarter to upwards of half an inch with alkali. Its condition is, in fact, so unfavorable that I have at all times questioned whether it is not rather to this, than to the alkali *per se*, that the difficulty of growing any thing in this section ought to be attributed. The alkali may be responsible in part for this condition, but there is no question in my mind but that the water is the direct cause of this to a greater extent than the alkali. The very great improvement caused by addition of the manure and straw to this soil is corroborative of this view. I see nothing in the addition of straw to modify in the least the effects of the alkali nor to diminish its quantity, but it does change the texture of the soil, permitting aeration and disintegration to a beneficient extent.

§ 30. The third crop grown on this section still leaves it somewhat doubtful whether we should charge any of the evil to the direct influence of the alkali. A few of the young plants were undoubtedly killed by it, but after they had become established it seemed to do them no injury. I believe it to be of far less injury than it is usually thought to be. Both the sugar content and coefficient of purity of samples taken from this section during the three seasons are slightly lower than in samples taken from the other two sections. There are exceptions to this statement, but they are not of sufficient importance, in number or degree, to cast any doubt on the fact that beets grown in this section are inferior to those grown on the other sections. They have, however, improved in quality during the three years. The average of all varieties grown in 1897 was 10.66 per cent. sugar in beet, with a coefficient of 73.3; in 1898, including both manured and not manured, the average was 12.68 per cent. sugar, 76.2 purity; and in 1899 the average was 14.13 per cent. sugar, 77.1 purity. This is a marked improvement in the quality of the beet. The figures represent the total improvement, including that due to the soil, to culture, and the differences in the season. The two latter are more important than we are at first inclined to think. A good year is a familiar expression, but its equivalent in tons of beets, or pounds of sugar, is a very indefinite notion, especially to those who use it most frequently. Though three years of observation is too brief a time to form an estimate of the seasonal influences on this crop. I am inclined to credit a large share of the improvement in the quality of the crops to this cause, and also something to the

differences in culture; but after making due allowance for these factors, there remains a decided improvement, due to the improved soil conditions, and, so far as I can now see, this improvement is wholly in its mechanical condition, brought about by the subsoiling, cultivation, manuring and by being left in ridges during the winter, exposing it to weathering. That it is not due to improved drainage is evident from facts which will be dwelt upon at a subsequent time.

§ 31. The important fact in this connection is simply this: That the water table has not been lowered, except temporarily by prolonged dryness or a lack of irrigating water.

In connection with this question, the influence of the height of the water table, an attempt was made to determine the capillary power of the soil. It was necessary to break up the natural compactness of the soil, so we passed it through a 40-mesh sieve and packed it as firmly as we could, by gentle tapping, into a glass tube, $1\frac{1}{8}$ inches in diameter. Experimenting in this manner we found that the water had passed upward $31\frac{1}{2}$ inches in seven weeks, and in one year and five months the soil was perceptibly moist at a distance of 45 inches from the water surface, and quite wet at 39 inches from the same. If these figures represent the value of capillarity in the soil in its natural, undisturbed condition, it would seem that our crops ought to have been pretty well supplied with water at all times, there being but a short time when the water level was more than 45 inches below the surface of the ground. The evaporation from the surface in the open field, exposed to a hot sun and the winds, is quite different from the evaporation from a small, shaded and protected surface, such as that exposed in my tubes. I I have made no attempt to determine how much of a part this may play in my experiment; I simply acknowledge that it has something to do with it, and that is all.

§ 32. I was at one time quite doubtful whether there was any drainage at all out of the area which I was cultivating, and thought to test the question by introducing some lithia chlorid into one of the wells and observe how long it would require for it to make its appearance in the adjacent wells. Lithia had been looked for in the analysis of the residues obtained from the ground water, and reported as absent, so I thought that my plan was feasible; but on examining the water more carefully, using larger quantities, I found it present in easily detected quantities. I had samples of the residues from the ground water, obtained during the preceding eighteen months, and an examination of these showed this element to be present at all times. I do not know whether this is true of other soil waters in this region or not. It, however, rendered this means of detecting a flow of water through our plot inapplicable,

but a subsequent experiment showed that the water level is lowered, by drainage or otherwise, from 0.7 to 1.0 foot in about 36 days. Observations, in 1898, on the rate of the fall of the water level after having raised it by irrigating, showed about 40 days as necessary for a like fall, *i. e.*, from 0.7 to 1.0 foot, in the different wells. The lowest point the water plane has reached below the surface of the ground, at the east end of the patch, corresponding to section 3, at any time during the three years, was 3.29 feet, which is less than the value of capillarity in this soil. Under such conditions of moisture it would seem that, in some respects, it would be an advantage, rather than otherwise, to have a long dry season. Such seems to have been the case, but not more so with this plot than with others more favorably conditioned.

THE DRY MATTER IN THE CROPS.

§ 33. The average percentage of sugar present in the crop of 1898 was materially higher than in the crop of 1897, and the crop grown by the Chemical Department in 1899 was very rich in sugar. I have already stated that in the latter years there was a scarcity of water, and that the rainfall during the latter part of the seasons was small, so that the soil became dry to a depth exceeding the length of the beets. I believed that this had the effect of increasing the dry matter in the beet, just as drying out under any other conditions would have done, and would account, in part at least, for the higher percentage of sugar. Accordingly, samples were taken, thirteen in number, ranging in weight from 800 to 10,500 grams, and the dry matter determined. The results ranged, in 1898, from 18.63 per cent. to 25.62 per cent., with an average of 22.00 per cent., as against 17.39 per cent. in 1897, when the range was from 16.69 to 18.01 per cent. These figures represent four varieties and seventy-two beets. The highest average obtained in 1897 was for the Kleinwanzlebener and Vilmorin, six beets each, which gave 18.95 per cent. as the highest percentage of dry matter, showing that there was an average of 3 per cent. more dry matter present in 1898 than in 1897, or at least one sixth more. In 1899 we find an average of 22.76 per cent., or three quarters of one per cent. more than in 1898; but this is with two varieties only, the Vilmorin and Zehringen. We did not find any difference between the beets which had grown on manured or unmanured sections in this respect. There were variations, but they were not constant in either direction. I think that this difference of from 3 to 3.75 per cent. in the total dry matter is mainly due to the difference in the seasons.

THE DRYING OUT OF BEETS.

§ 34. During the season of 1898 we received a considerable number of samples from different parts of the State and the results

were uniformly high. An attempt was made to obtain the weight of the fresh samples, but it was very unsatisfactory. I was informed that it was impossible for many of the parties to obtain the weight of the samples sent with any degree of accuracy, and this must have been the case, for quite a number of the samples received weighed more by 250 grams than when they were mailed to us, from three to five days previously. Why the senders should give us such under weights is not easy to understand. In spite of these accidents, we obtained 336 samples which we considered usable, in estimating the deduction to be made from the average percentage of sugar found in order to approximate the actual percentage in the beets in a fresh condition. The amount of drying out was very varying, often evidently too low, and sometimes so high that the result obtained had to be rejected as improbable; but none of the low ones were rejected and are included in the 336 samples used. The correction to be applied as based on these is 1.49 per cent. These samples were all wrapped separately in paper and inclosed in a cotton sack or cloth. As the weights given by the senders were unsatisfactory, I repeated the experiments of 1897 with even more care, having regard to the temperature at which the room was kept during the time of the experiment. The mean temperature for September, during that portion of it in which we received samples, was 61.3°, and for October it was 46.3°, but the mean maxinum was 61.0°. I endeavored to keep the room about 60°. I took 4,660 grams of beets and obtained the following results, the loss being expressed in percentage of weight at beginning of the twenty-four hours.

TABLE III.—SHOWING THE RATE OF DRYING OUT OF BEETS.

Days.	*Weight. Grams.*	*Temperature of Room. Degrees.*	*Percentage of Loss.*
—	4660.0	.....	....
1	4460.0	57–66	4.39
2	4322.0	56–62	3.08
3	4182.0	56–57	3.24
4	4066.0	57–62	2.77
5	3915.0	57–62	3.71
6	3801.0	57–62	2.91
7	3695.0	57–65	2.79
8	3617.0	60–60	2.11
9	3547.0	.....	1.93
10	3468.0	.....	2.23
11	3391.0	57–60	2.17
12	3305.0	60–67	2.42

§ 35. The conclusion arrived at in 1897, was that the maximum loss was 5.4 per cent. for the first 24 hours, and that after a few days it fell to about 2 per cent. and remained quite constant up to 17 days. The experiment just recorded was made under similar conditions as those in 1897. The beets were covered with gunny sacking to protect them from light and to protect them from drafts

of air as much as possible. In 1897 the loss in the first 12 days varied from 30 to 33 per cent. of the original weight of the beets; in 1898 we obtain 29.00 per cent. loss, and after the first seven days the daily loss is roughly 2 per cent.

As but few samples received from different parts of the State were analyzed sooner than five days after being harvested, the deduction of one and one half per cent. on account of drying out is quite within reasonable limits, as according to the most favorable results obtained by experiment, a deduction of upwards of 2 per cent. would be allowable. Our own samples were analyzed within 24 hours after being taken and lost less, and tend to correct the error and justify us in taking the lower figure, 1.5 per cent.

§ 36. The importance of this is apparent if we consider the effect of it in stating the average percentage of sugar in the crop of 1898. We have 813 samples of this crop and the average of the analyses as made is 15.12 per cent., but allowing for the drying out by deducting 1.5 per cent., we have 13.62 per cent. as the average, which I believe is the nearest approach to the truth that we can make.

§ 37. The records of this department show that the average of all samples recorded from 1888 to 1896 inclusive, is 12.8 per cent., according to which the crop of 1898 was above the average.

§ 38. It should be remembered that the question of drying out is of much greater importance in considering small samples sent to the Station than it would be in samples taken from car-load lots sent to a factory. The factory sample would be likely to be nearer correct than the sample sent to some chemical laboratory to be tested.

COEFFICIENT OF PURITY.

§ 39. In connection with the last question, that of the coefficient of purity is of some importance, not as to what extent it is effected by the drying out, but as to how near the truth the ordinary determination comes. Two series of experiments were made, five with Vilmorin and six with Kleinwanzlebener. These beets ranged in sugar from 9 to 14 per cent., and the coefficient obtained by evaporating to dryness to determine the total solids was sometimes higher and again lower than that found by the ordinary method, but the average of the five determinations made with the Vilmorin was the same and that with the six Kleinwanzlebener samples differed by 0.2 per cent. The average obtained as ordinarily determined being higher by this small amount.

THE EFFECT OF SIZE OF BEETS ON PERCENTAGE OF SUGAR.

§ 40. The impression is that large beets will be low in sugar and that small beets will be rich in sugar. I do not recall having seen it so stated by any one writing on the subject. It is, however, claimed, and that justly, that medium sized beets are apt to be richer in sugar than larger ones, and under ordinary conditions they will be richer than very small ones. It should be remembered that such statements are only true in a general sense and do not exclude exceptions either way. Having seen so many exceptions to the statement that large beets were apt to be poor in sugar, I endeavored to determined the influence of size upon the percentage of sugar.

We sometimes find large beets in a row where the stand is regular, and the large and small beets have, to all appearances, had equal chances, with the general conditions favorable to the formation of beets rich in sugar. Again we find beets grown under conditions which we know from observation to be unfavorable to the growth of beets rich in sugar, whether they are large or small. Again, we know that beets grown from different seed, and on different plots of ground, differ in quality. I shall give examples showing this to be the case with different parts of rows, one end yielding markedly better beets than the other, without regard to size.

§ 41. In order, then, to study whether a large size has any prejudicial relation to the sugar content, I took beets of different sizes grown under the same conditions, *i. e.*, I took all of the beets growing in a certain length of row and analyzed each one separately where they were large enough to make a sample; if not, two were taken together.

This was done with a number of rows, and the results are given in the following table:

TABLE IV.—RELATION OF SIZE OF BEETS TO SUGAR CONTENT.

Number.	*Weight of Beet in Pounds.*	*Percentage of Sugar in Beet.*	*Coefficient of Purity.*
1	4.40	13.35	79.6
2	4.00	14.16	73.0
3	3.25	14.96	81.9
4	2.90	16.06	85.1
5	2.60	14.77	80.8
6	2.40	14.44	76.8
7	1.75	16.96	82.5
8	1.60	15.39	79.7
9	1.50	15.06	81.0
10	1.50	15.68	83.1
11	1.45	16.44	79.9
12	1.20	15.77	85.8
13	0.75	14.73	77.5
14	0.62	15.44	81.0
15	0.62	15.58	83.4
16	0.62	12.97	70.3
17	0.50	14.30	74.5
18	0.40	14.58	78.0

§ 42. This set of samples shows that beets ranging from 1.20 to 1.75 pounds, Nos. 12 to 7 inclusive, are preferable to either larger or smaller beets. It happens that we have six beets ranging from 2.4 to 4.4 pounds, showing an average of 14.62 per cent. of sugar, and six beets weighing less than a pound each, whose average sugar content is 14.60 per cent. I consider this a reasonably fair test of this point, as the samples are of the same variety and taken consecutively, and from a portion of the rows where the stand was perfect. The beets were mature and in fine condition.

§ 43. Another set of samples was taken of another variety which had grown near an irrigating ditch, and near the edge of the patch. I knew that these conditions tended to the growth of large beets of low quality. But I desired to see what the relation of size to quality was in these. This variety was not known. The seed was purchased for Lane's Imperial, but they were not Lane's Imperial, being a sugar beet of the type of the Kleinwanzlebener, and but little inferior to this variety when grown under like conditions. This variety, under fairly favorable conditions, showed an average of 13.25 per cent. sugar, against 13.97 per cent. for the Kleinwanzlebener. A sample of this variety, grown on my own plot and taken a few days before these, showed 12.59 per cent. sugar, with a coefficient of purity of 77.6.

TABLE V.—RELATION OF SIZE OF BEETS TO SUGAR CONTENT—(Continued).

Number.	*Weight of Beets in Pounds.*	*Percentage of Sugar in Beets.*	*Coefficient of Purity.*
1	8.62	10.59	67.5
2	8.12	10.45	68.3
3	6.90	9.64	62.5
4	5.70	9.50	65.2
5	5.16	10.45	65.9
6	3.15	12.11	72.3
7	2.88	10.45	67.0
8	2.82	9.26	62.1
9	2.71	10.21	64.7
10	2.27	8.46	66.6
11	2.01	9.98	66.0
12	1.78	10.45	66.5
13	1.55	12.35	70.1
14	1.08	10.45	65.9
15	0.25	11.88	69.7

§ 44. This set of samples is no more decisive than the preceding. If it shows anything, it is that beets from one quarter to one and three quarter pounds will be better than larger beets; but taking the individual beets, we observe that the eight-pound beets are as good or better than the one pound sample, and that the three-pound sample is better than the one quarter pound one. The size seems less determinative under conditions of abundant moisture and favorable soil conditions than under others.

§ 45. Being altogether dissatisfied with the results of these observations, I thought to eliminate the variation in the individual beets by digging a section of a row, dividing the beets according to weight into different samples, and determining the sugar in these. Further, to decrease the chance of error by happening to get either too good or too poor a sample, I took two sections of each row, one from the east half and one from the west half, and further still, I took four varieties. The east half and west half of the patch received the same treatment, except in one particular. The distance to which all of the beets so far mentioned were thinned was from 6 to 8 inches. The results are interesting, and are given in the following table:

TABLE VI.—RELATION OF SIZE OF BEETS TO SUGAR CONTENT—(Continued).

VARIETY.	East Half.						West Half.					
	Number of Sample.	Number of Beets.	Average Weight of Beets.	Average Distance Between Beets in Inches.	Percentage of Sugar in Beets.	Coefficient of Purity.	Number of Sample.	Number of Beets.	Average Weight of Beets.	Average Distance Between Beets in Inches.	Percentage of Sugar in Beets.	Coefficient of Purity.
Vilmorin Improved...	1	9	2.72	7.3	13.11	75.5	....	7	1.51	8.25	15.06	81.7
	2	4	2.49	.....	13.30	75.0	....	13	1.05	......	16.15	83.3
	3	11	1.56	......	13.90	79.2	....	9	0.43	......	15.11	79.5
	4	6	1.05	......	13.78	78.2	....	...	......	......	....	......
	5	6	0.62	......	13.78	75.8	....	....	......	.....	....	......
White Imperial	6	4	3.30	6.99	12.11	69.3	....	3	2.66	6.66	13.07	72.4
	7	9	2.33	......	10.40	64.8	....	6	1.49	......	13.68	75.8
	8	13	1.46	.....	11.88	70.9	....	16	0.97	......	14.73	80.0
	9	11	1.00	......	11.64	66.4	....	11	0.58	......	12.88	70.9
	10	12	0 46	.....	12.30	68.1	....	...	......	......	....	......
White French.........	11	4	3.82	8.13	11.92	76.8	....	11	2.36	9.3	13.68	73.7
	12	6	2.45	......	14.25	84.3	....	9	1.70	......	13.44	72.4
	13	4	1.67	......	14.25	86.0	....	4	1.12	......	14.20	70.3
	14	4	1.17	......	13.44	72.2	....	7	0.49	......	14.73	74.8
	15	13	0.60	......	13.35	71.9	....	....	......	......	....	......
Dippe's Improved Kleinwanzlebener...	16	4	2.22	6.3	15.25	76.3	....	14	1.42	6.48	16.63	79.8
	17	7	1.66	.... .	15.77	77.1	....	11	0.97	......	16.37	77.9
	18	10	1.09	......	15.34	75.0	....	12	0.48	......	16.58	75.7
	19	17	0.48	......	15.91	74.7	....	....	......	.....	....	......

§ 46. The beets from the west half are by far better than those from the east half, and this, too, without regard to size, so that the beets from the two halves cannot be compared with one another. The number of beets exceeding 1.5 pounds from the east half stand to those from the west half as more than 2 to 1. The length of row dug was carefully measured, and the distance apart in the row determined; for the Vilmorins it was 7.3 inches in the east, and 8.25 inches in the west half; for the White Imperial it was 6.99 in the east and 6.66 in the west half; for the White French, 8.13 inches in the east and 9.3 in the west half, and for the Dippe's Kleinwanzlebener it was 6.3 in the east and 6.48 inches in the west half. The distance between the beets is well within the generally assumed proper limit. The shortest section of row dug was 20 feet, and the length of the rows was 400 feet.

§ 47. A casual inspection of the table leaves the impression that the beets from the west end of the patch are smaller than those from the east half, and are richer in sugar than these. This is true, but I do not believe that the rest of the inference likely to be drawn, *i. e.*, that it is because of their smaller size that they are richer, is justified. I believe that this depended upon some other factor.

§ 48. It is difficult to satisfy oneself by a study of the results given in this table that there is anything shown by it more definitely than by the preceding ones. Taking each of the samples by itself, that is, comparing beets grown side by side, we find only two sets in the six where there is any decided difference in favor of the smaller beets, and these two are of the same variety, the White French, and the larger beets weigh from 3 to 7 times as much as the smaller beets. We cannot even allow this uncertain advantage to the smaller beets, in regard to coefficient of purity, for, according to the table, the difference is in favor of the larger beets. If from this table we select beets of the same size for comparison, we will find that those from the west end are the richer and better beets. The few exceptions which we find to this statement are confined to the White French variety. If we had dug the whole of the rows, and selected all of the beets weighing upwards of two pounds, we would have gotten at least two thirds of the sample from the east half of the patch, and if we had, in the same manner, collected a sample of beets weighing less than one pound, we would have gotten more than half of it from the west end, and these samples would not give us the data to judge of the relation of size to percentage of sugar. It would be, in a considerable degree at least, equivalent to comparing the large beets grown in the one half with the small beets grown in the other half, which conceals the relation between the size of the beet and its percentage of sugar.

If from the preceding table we take the average of all the samples in which the individual beets exceed two pounds, and compare it with the average of all those in which the beets weighed less than one pound, we find a difference of 1.5 per cent. sugar in favor of the small beets, which is actually a greater difference than is shown between the largest and smallest beets in any single experiment in the series. In order to make this comparison, we must take beets grown side by side, which we have endeavored to do, finding as the result of the eight experiments recorded in the last table, that beets weighing about one half pound contained, as compared with beets weighing upwards of two pounds, in one case more than 1 per cent. more sugar, in two cases more sugar by 0.67 per cent., in one case more by 0.19 per cent., and in one case less by 0.19 per cent. Of four varieties experimented with, the maximum difference shown by three of them in favor of the small beets is 0.67 per cent., while the fourth shows a difference of a little more than 1 per cent.

§ 49. The second table given under this subject, being the results obtained from an experiment with beets of very large size, and grown at or near the edge of the patch, with a constant and abundant water supply, suggested an explanation for the general impression that large beets are poor beets. Excessively large sugar beets, 8 to 10 pounds or upwards, are unusual. Such beets are grown under such conditions as above given, at the edge of a patch with abundant water and plant food, or where they stand alone. I have analyzed Kleinwanzlebener beets grown in this manner that were very poor, showing less than half as much sugar as the average of the patch. In other words, very large size and low quality are associated with an almost unlimited feeding ground and abundance of water. There was a single row of beets on the Farm which had practically been grown under these conditions, except that the beets were thick in the row. There were three varieties: Vilmorin, White French and White Imperial. Samples of each of the varieties were taken by digging a piece of the row and sorting the beets into different lots, according to size.

TABLE VII.—EFFECTS OF EXCESSIVE FEEDING GROUND ON QUALITY OF BEETS.

VARIETY.	Number of Beets.	Average Weight of Beets in Pounds.	Percentage of Sugar in Beets.	Coefficient of Purity.	Percentage of Sugar in Beets Grown in Patch. Rows 18 inches, Beets 8 inches.	Coefficient of Purity.
Vilmorin	6	2.02	12.78	75.5	.....	....
	9	0.50	14.30	80.0	13.97	79.2
White French	9	1.95	11.50	73.0	.....	....
	12	0.33	11.82	72.2	13.16	80.3
White Imperial	10	1.56	10.31	68.5	.....	....
	3	0.84	11.50	74.2	.....	....
	13	0.17	10.59	70.7	11.88	70.9

§ 50. This exhibits the effect of growing free, which would probably have been more pronounced had the beets not been so crowded in the row. The Vilmorins averaged one beet to each 3.4 inches, the White French one to each 3.5 inches, and the White Imperial one to each 2.4 inches. This made the beets so thick that they pressed one another outward from the row, and modified the effect of the row being single and with an excess of room laterally. In the case of the Vilmorin there is a decided superiority shown by the small beets in both percentage of sugar and coefficient of purity, 1.5 per cent. in sugar and 4.5 in purity. The other two are so close that it is not decisive. The average of the Vilmorin is so close to the value found for the sample taken from the patch that it is not clear that the difference is due to the amount of space at the disposal of the beets. In the other two, however, there is a difference of one and one and a half per cent., respectively, in favor of the beets grown in the patch. The two soils in which these samples were grown are equally good, so far as one can judge.

§ 51. My conclusion is that in the case of beets growing side by side, those ranging in weight from one to two pounds are richer in sugar, and of higher purity, than either the larger or smaller, and of the latter that there is a slight difference in percentage of sugar in favor of the smaller beets. But the difference in purity is slightly in favor of the larger beets, and in neither case is the difference great or constant. But large beets, grown under conditions differing from those under which the smaller beets have been grown, cannot be compared with the smaller ones. I also take it, as indicated by the values obtained from the samples from our

single row, that two great a width between the rows tends to have the same effect as permitting the beets to grow singly.

EFFECTS OF OVER IRRIGATION.

§ 52. The difference in the size of the beets, it being smaller, and their sugar content, it being higher, in the west end of one of our patches than in the east end, seemed difficult to explain, as the patch was only 400 feet long, and the soil seems equally good throughout. Our field notes, however, call attention to the fact that the west end is hard and the foliage is yellow, as though water had stood there, puddled the ground and produced the yellowness of the leaves. As this was the only perceptible difference in the conditions at the east and west ends, there remained nothing else to which to attribute the difference in the quality of the beets. There was another patch on the Farm in which this had happened, and we collected samples from this patch also and analyzed them, together with samples taken from the same patch, but which had not suffered from this cause. It appears from the table on page 27 that the average of all the samples taken from the west end exceeds by 0.71 per cent. that of all the samples from the east end. An examination of the table in detail shows how constantly the samples from the west end were better than those from the east end, though the average difference is only 0.71 per cent. The samples obtained from the other patch, consisting of eight beets each, the one yellow from the effects of too much water, the other taken a few feet away but green and healthy looking. The beets of both samples were small. In the green sample they averaged 0.62 pound. This sample showed 13.78 per cent. sugar and 79.1 purity. In the over irrigated sample the average weight was 0.66 pound. This sample showed the presence of 17.20 per cent. sugar and 89.1 coefficient of purity. It was at this time so late in the season that we could not follow this subject, and postponed further observations until the next season, 1899. I was, in a certain sense, thwarted in this part of my work; but in another sense I was not. In making an experiment with irrigating water I had an opportunity to over irrigate my beet plot and subject it to a treatment reproducing the conditions of these over-irrigated patches.

§ 53. My plot did not need water, but wishing to make observations on the changes in the amount of solids, etc., which go into solution and pass into the ground water, I obtained, through the kindness of Capt. Hawley, our Water Commissioner, enough water to thoroughly soak the ground, raising the water plane quite to the surface. This irrigation was made August 31 to September 2 inclusive. The ground was not disturbed, but allowed to settle and become hard. The beets were left to themselves until dug. The ground did become hard, and the beets showed the effect of

over irrigation by turning yellow in places. The average for this plot in 1898 was 13.65, and the average for all samples analyzed at the Station that season was 13.62 per cent. The average for this crop, 1899, which was over-irrigated in early September, was 14.69 per cent. I have no way of judging whether I diminished the yield by treating the crop as I did, but it was the largest yield that I have yet gotten off of this ground. The size of the beets in the over-irrigated patches of the season of '98 give contradictory indications. It seems probable that the yield would be diminished, but it certainly was not materially affected in any of the observed cases.

§ 54. These facts seen to contradict the generally accepted view that a rainfall in the latter part of September or early October may effect the beets unfavorably. I recorded, in 1897, the effect of a rainfall of about .75 of an inch as depressing the sugar content to an extent which the beets did not overcome for three weeks. I think that the explanation is not difficult. A moderate rainfall may do one of two things, according to the condition of the crop at the time of its fall. If the crop is growing slowly, but has not begun its rest period, the rain may very materially increase its rate of growth, and an increase in weight of crop may take place more rapidly than the formation of sugar. This would produce a depression in the percentage of sugar present, but the percentage might be subsequently regained or exceeded. If the crop had already begun its resting period, had begun to ripen, the rain might, as it often does, produce a new growth, that is, a second growth, in which new leaves are produced, a fact familiar to every one. In this case there is a real diminution of the sugar present, and not only an apparent one due to a disproportionately large increase in the weight of the crop. In the over irrigation we have neither of these cases. On the contrary, the effort was to keep the beets growing steadily, but to puddle the soil tightly about them at a period not too much in advance of their normal time of maturing and then to leave them. I do not believe that the same results would follow in all soils, nor if the excessive irrigation should be applied at a time when it would cause the crop to take on a new growth, but there does seem to be enough promise in it to justify a sufficiently extensive series of experiments to determine the exact conditions of soil and time when it will produce advantageous results, as there is no doubt but that such conditions exist.

BEET ASH AND ITS COMPOSITION.

§ 55. In 1897 I endeavored to determine the ash at different periods in the development of the beet, and the effect of the different soil conditions upon the composition of the ash. There was a series of analyses of beet ashes, seventeen in number, made during the

season. Thirteen of these ashes represented varieties of sugar beets, mostly the Kleinwanzlebener variety. The reason that my work was confined to this one variety was that the results obtained showed so little variation that the information to be obtained did not promise to be commensurate with the labor involved. Our conclusion from that series of analyses was, that probably owing to the richness of the soil in the elements of plant food necessary for the beet, the alkali present had exerted but little or no influence on the composition of the ash. The ash in that series which showed the largest amount of soda was one prepared from beets grown on a Farm plot free from alkali, or as much so as any of our soils. The only thing which we observed in the analyses which might be taken as indicating anything characteristic of the soil, was the tendency shown toward a high chlorin percentage. We have not endeavored to study this subject in such detail in the subsequent years, but have reduced the number of samples, enlarging them at the same time, so as to make them thoroughly representative. As we had selected the Kleinwanzlebener variety in 1897, we selected it also in 1898. The samples were not only of the same variety, but were grown on the same ground, so the ashes ought to give us a measure of the influence of the manure applied, and the effect of the cultivation if the composition of the ash is materially affected by these factors. Our conclusion in 1897 in regard to this point, was that the composition of beet ashes was relatively constant, within comparatively narrow limits. The following analyses corroborate this view, though they are not given for this purpose:

TABLE VIII.—GIVING COMPOSITION OF ASHES OF BEETS GROWN WITH AND WITHOUT MANURE.

	Kleinwanzlebener. Chemical Plot Manured. 1898.	Kle nwanzlebener. Chemical Plot. Not Manured. 1898.	Kleinwanzlebener. Chemical Plot. Not Manured. 1897.	Vilmorin Improved. Farm Plot. Not Manured. 1898.	Vilmorin. Farm Plot. Not Manured. 1897.	Vilmorin. Chemical Plot. Not Manured. 1899.	Zehringen. Chemical Plot. Not Manured. 1899.
Dry Matter in Beets	19.770	20.822	18.090	23.704	17.500	23.493	24.423
Ash in Dry Matter	5.650	5.433	6.491	5.476	5.469	4.000	4.500
Insoluble Ash	1.075	0.921	1.389	0.850	1.311	1.350	1.150
Soluble Ash	4.575	4.512	5.102	4.626	4.158	2.650	3.350
Ash in Fresh Sample	1.117	1.131	1.174	1.298	0.957	0.940	1.099
Carbon	Trace.	Trace.	Trace.	Trace.	Trace.	Trace.	Trace.
Sand	1.440	1.079	1.188	1.125	0.931	2.613	2.139
Silica	0.946	0.887	1.102	0.652	1.264	1.373	1.234
Sulphuric Acid	2.760	3.062	3.476	3.364	2.878	3.747	3.913
Phosphoric Acid	9.984	8.434	8.668	6.923	6.088	8.613	9.109
Carbonic Acid	18.106	17.092	15.690	22.300	19.177	16.890	15.294
Chlorin	10.752	11.857	12.599	6.966	10.887	5.699	9.464
Potassic Oxid	40.061	37.923	42.976	38.322	40.065	40.525	38.572
Sodic Oxid	8.699	12.184	8.811	12.736	11.161	5.878	9.219
Calcic Oxid	2.549	2.612	1.951	2.356	3.409	4.106	2.900
Magnesic Oxid	5.745	5.366	5.573	5.156	5.264	7.226	7.242
Ferric Oxid	0.273	0.306	0.146	0.238	0.414	0.396	0.707
Aluminic Oxid	0.087	0.303	0.538	0.100	0.774	0.184	0.193
Manganic Oxid	0.195	0.331	0.195	0.152	0.186	0.310	0.204
Loss on Ignition	1.519	1.626	....	1.532	....	3.454	2.308
Sum	103.109	103.062	102.912	101.922	102.498	101.014	102.498
Oxygen Equivalent to Chlorin	2.423	2.672	2.839	1.570	2.441	1.284	2.132
Total	100.686	100.390	100.073	100.352	100.057	99.730	100.366

§ 56. This table shows the composition of beet ashes obtained from beets grown on three different soils and under different conditions, both of season and cultivation. The differences in the percentage of dry matter in these samples are, as I have already suggested, to be attributed to seasonal influences rather than to differences due to variety and cultivation. But whether the other differences, such as is observed, for example, in the percentage of the phosphoric acid, is to be attributed to the differences in the soils, season or cultivation, appears open to doubt, though the

higher percentage of this acid in the ash of beets grown on the manured ground indicates that the cultivation has an influence upon the amount of this component of the ash, tending to increase it. On page 48, Bulletin 46, is given an analysis of the ash of a sample of Kleinwanzlebener beets grown in New Mexico, in which we have less than 4 per cent. (3 336 per cent.) of phosphoric acid, showing that ash from the same variety may have a varying composition, due to differences of soil, and it may be that the lower phosphoric acid in the Vilmorin ashes, given in the table, is due to this and not to variety, for these samples were grown on different plots in 1897 and 1898, while the Kleinwanzlebener samples were grown on the same plot, one half of which, however, had received a dressing of manure. The percentage of chlorin shows the greatest change as a result of the cultivation and continued cropping. In 1897 the ash of the Kleinwanzlebener beets contained 12.599 per cent. of chlorin; in 1898, grown on the portion which had not been manured, the ash contained 11.857 per cent., and the ash of the beets grown on the manured portion contained 10.752 per cent. The highest percentage of chlorin found in the ashes of the Zehringen variety, in 1899, was 9.464 per cent., while the Kleinwanzlebeners showed only 5.699 per cent. chlorin present in the ash. These last two samples were grown on soil which had not at any time received a dressing of manure. These percentages indicate a decrease in the amount of chlorin taken up by the beets, as the soil conditions are improved. There has been, at the same time, an improvement in the quality of the beets. In 1897 the Kleinwanzlebener variety showed 11.76 per cent. sugar, 76.0 purity; in 1898, 13.97 per cent. sugar, 84.6 purity; in 1899, 15.34 per cent. sugar, 80.8 purity. For two years, 1897 and 1898, the percentages of sulphuric acid, phosphoric acid, lime and magnesia remained almost the same. In 1899, however, the percentages of lime and magnesia increased by about 1 per cent. in each case. Previous to 1899, the highest percentage found for the magnesia was 5.74 per cent., but in 1899 it reached 7.25 per cent., an increase of 1.5 per cent. In the case of the lime, the highest percentage found, in 1897 and 1898, was 2.826 per cent.; in 1899, 4.106 per cent.; also an increase of nearly 1.5 per cent. These samples were grown on the same plots, and were of the same variety of beets. The changes observed are toward a closer agreement with other analyses than heretofore. These percentages do not establish permanent changes, but do show the tendency which the continued cropping and cultivation of this soil has to modify its effects upon the mineral matters taken up by the plants. The tables giving the percentage of sugar and the coefficient of purity for these crops show a decided improvement in the three years covered by the experiments, and the analyses of the ashes show the tendency which manuring,

cultivation and continued cropping to the same crop, has to ameliorate the effects of unfavorable soil conditions.

§ 57. Reference was made to the question as whether the manure added to the soil, acted, in this case, as a fertilizer or as a mechanical agent, simply improving the physical condition of the soil. The composition of the ash shows that its action is not merely physical but is well marked chemically, in that the percentage of chlorin is lowered and that of phosphoric acid is increased.

§ 58. Reference to the Tables Nos. I. and II., showing the percentage of sugar, etc., for the years 1898 and 1899, will show that the effect of the manure upon the sugar content and coefficient of purity was not marked until the end of the season, or the period of ripening. This was especially true in 1898; the difference in favor of the not manured plots being greater in 1899 than in 1898. It should, however, be borne in mind that all of the beets in '99 are remarkably high in sugar, and quite up to the average in purity, and while the beets grown on the plots having received no manure were better than those grown on plots which had received manure, it is not to be inferred that the latter were poor beets in regard to either sugar content or purity, for the averages for the two varieties grown on the manured plots in 1899 were 15.06 per cent. sugar, 81.7 purity, and 14.15 per cent. sugar, 77.7 purity, while those grown without manure showed 15.34 per cent. sugar, 80.8 purity, and 16.24 per cent. sugar and 84.5 purity.

The effects of the straw were probably almost wholly mechanical, and this effect was very evident. The effect of the sheep manure was evident in the improvement of the physical condition of the soil, in the germination of the seed, the more vigorous growth of the crop, the shape of the beets, the sugar content of the beets, the coefficient of purity, and in its effects upon the composition of the ash.

§ 59. The effects of the manure upon the vigor of the growth, the percentage of sugar and the coefficient of purity were quite as marked in the second as in the first crop grown on the soil after the application of the manure. The manure being more thoroughly incorporated with the soil the second year, did not produce as marked effects upon the shape of the beets as it did the first year.

COMPOSITION OF THE MANURE APPLIED.

§ 60. It has already been stated that the amount of manure applied was at the rate of sixty-four tons to the acre, also that it was applied broadcast in February and plowed under in May. At the time of the application of the manure, my opinion was that this soil was so abundantly rich in plant food that the only effect of the manure would be mechanical. The results observed show that

its effects were varied, and it apparently produced important chemical changes in the soil, because of its fertilizing ingredients.

§ 61. This manure contained, at the time of its application, 45.14 per cent. of dry matter, or 28.89 tons of dry matter was applied per acre.

§ 62. The ammonia in the fresh manure was equal to 0.926 per cent. of nitrogen. This determination was made by distillation with magnesic oxid, to learn how much of the total nitrogen existed in the manure in the form of ammonia and ammonia salts; also to learn how great a loss might be suffered by the volatilization of this compound under the influence of our winds and sunshine. The loss in our particular case was probably large, as the weather remained clear for some time after the application of the manure, and dried it out until it became very dry. The percentage of the total nitrogen, which was set free as ammonia by the magnesic oxid, was 47.22 per cent., and the amount expelled by drying the manure to a constant weight in a water oven was 60.73 per cent. of the total. I do not know the power of this soil to absorb the ammonia which was ready formed in the manure, but it is evident that the danger of loss was, under the conditions given, greater than one would expect. Had rain fallen immediately after the application, the loss would have been much smaller than it probably was.

§ 63. The total nitrogen present in the manure was 1.940 per cent., or the nitrogen applied was at the rate of 2,483.2 pounds per acre; or if we allow a loss of one fourth of the nitrogen, due to volatilization and failure of the soil to absorb the ammonia, there would remain 1,861.6 pounds to the acre. The phosphoric acid in the fresh manure was 0.654 per cent., or an application of 837.1 pounds, equivalent to 1,573.4 pounds of calcic hydric phosphate per acre.

§ 64. The potassic oxid equaled 2.427 per cent of the fresh manure, or a dressing of 4,077.36 pounds of potassic oxid to the acre, equivalent to 8,543.11 pounds of potassic sulphate. We have the application of 2,483.2 pounds of nitrogen, 1,573.4 pounds of calcic hydric phosphate and 8,543.1 pounds of potassic sulphate, or their equivalent, together with nearly 25 tons of organic matter, producing the effects recorded in the preceding pages.

§ 65. The most salient question suggested by a comparison of the composition of the manure applied and the results produced, is in regard to the phosphoric acid and potassic oxid, the former being materially increased in the ash of the beets, while the latter, on the contrary, is not effected, or is possibly decreased. The amount of potassic oxid applied is greatly in excess of the phosphoric acid, and the ratio of the potassic salts to the phosphates in the manure is

greater than the ratio of potash to phosphoric acid in the ash. The effect of the manure is probably to be found in the specific action of the nitrogen and the organic matter. I think that the analyses of the soil will tend to establish this view.

§ 66. The nitric acid in the ground water in 1898 is more variable and much higher than it was in 1897, but on the other hand, the water level stood somewhat higher in 1897 than it did in 1898, the difference being about one foot. I think that the smaller quantity of water applied to the surface in 1898, either as irrigation water or as rain, tending perhaps to yield a more concentrated percolate, will not account for the greatly increased amount of nitric acid in the ground water, but that it is to be explained chiefly by the oxidation of the nitrogen added to the soil in the manure.

§ 67. The total solids in the ground water in 1898 were higher, as a rule, than in 1897, but whether they were as much higher as the supply of water was less, I cannot say. I know that it does not hold good that the total solids in the water are larger in amount as the water is lower. The greater the depth of soil the water has to travel through, the less likely we are to find excessively large amounts of the total solids in the water.

§ 68. In 1899 we had a larger amount of water as sub-irrigation water, and it may be doubted whether the total solids contained in the ground water should be used as a criterion of the effect of the manure, *i. e.*, as a measure of the chemical changes induced by the manure. I regret that the relation here is so obscure and involved that it lessens the value of the results obtained, but our observations show that the total solids fell again in 1899 to a lower point than they showed in 1897.

Irrigation or heavy rains which fill the soil with water, raise the water level, and cause an increase in the chlorin contained in the ground water. The manure applied seemed to make the increase more pronounced and of greater duration.

The analyses of the ground water in 1898 do not show a sufficiently marked difference to justify any further inferences than those based upon the nitric acid and chlorin. We shall discuss this part of our work more fully in the succeeding part of our study.

§ 69. The effects upon the crop indicate that the manure applied produced not only mechanical effects upon our soil, but also chemical effects, both tending to improve its condition and eliminate the effect of the alkali in increasing the percentage of ash. But it is not clear what relation exists between the composition of the manure and the general effects produced. The observations made upon the effects of the straw, and the increased amount of nitric acid in the water (it is understood that this nitric acid is present in

the form of nitrates), incline me to the view that the organic matter, including the nitrogen, played an important part in our particular case.

SOAKING EXPERIMENTS.

§ 70. It is a universally acknowledged fact that the maturing of the beet is accompanied by an increase in the coefficient of purity; that is, that the sugar in the juice of ripe beets constitutes a larger percentage of the total solids than it does in the juice of green beets. The percentage of sugar in the ripe beet is also higher than in the same beet when it is green. The increase in the ratio of the sugar to the solids not sugar, might be due to an increase in the amount of sugar, without any change in the amount of the other solids, in which case there would be an increase in the weight of the beets, corresponding to the increase in the amount of sugar and of the dry matter in the beet. There is, however, a disappearance of solids not sugar at this period, which indicates that the percentage of total solids in the beet is not maintained at an approximately constant figure by a proportional increase of crop and sugar content, but a proportional decrease of the one and increase of the other.

§ 71. The following experiments were made in an endeavor to obtain more definite information on this subject, *i. e.*, whether this change of material into sugar may continue after the beet has been pulled; for if we can prove an increase in the amount of sugar, before and after soaking, the probability of such a change in the living beet is strengthened. In 1897 we found that there was a period during which sugar was rapidly formed, but that sugar was present early in the history of the crop, and that there was a slow increase, after the growing season for the crop had passed, even extending up to the early part of January, the beets having been left in the ground and covered with straw.

In 1898 a different experiment was performed. Four varieties of beets were chosen, Vilmorin Improved, White Imperial, White French and Kleinwanzlebener. Sixty-eight beets of the first and sixty of each of the last three varieties were taken, and after washing were paired, according to size, and one of each pair taken for immediate analysis, while the other was taken for soaking. The halves of the samples obtained in this manner varied but little from one another, the maximum difference being six pounds on a sample weighing 132 pounds. One half was analyzed immediately, the other half was packed in galvanized iron tubs, with fine sand, in such manner that the beets did not touch one another; water was added till the tubs were full, and pieces of ice were placed on top of them. The samples were soaked in this manner for seven days. The temperature of the water in the interior of the sand ranged from 41° to 48° F. throughout this time. The results were as follows:

TABLE IX.—SHOWING THE EFFECTS OF SOAKING BEETS ON THE SUGAR CONTENT.

Year.	Variety.	Before Soaking. Number of Beets in Sample.	Before Soaking. Weight of Beets in Pounds.	Before Soaking. Pounds of Sugar.	Before Soaking. Purity.	After Soaking. Pounds of Sugar.	After Soaking. Coefficient of Purity.
1898	Vilmorin Improved	34	65.00	8.2435	76.5	9.7657	78.8
	White Imperial	30	59.50	6.8960	74.0	7.0420	74.4
	White French	30	67.40	8.8698	80.3	8.8797	86.1
	Kleinwanzlebener	30	24.70	3.3789	77.0	3.5644	83.5
1899	Zehringen	30	35.12	5.2020	78.7	5.6451	84.4
	Zehringen	15	18.43	2.5913	77.2	2.7628	83.8
	Vilmorin	30	42.20	6.6549	82.0	6.8959	82.7
	Vilmorin	15	19.25	3.0560	84.2	3.1086	82.5
Average				5.6115	78.7	5.9580	82.0

§ 72. The samples taken were large enough to eliminate the errors in sampling, any effects of size of beets, and also any effects which might be attributed to variety. The same experiment was repeated twice in 1899, using two varieties. The series of experiments is wholly consistent in showing an increase in the amount of sugar after the seven days' soaking. I regret that I have not tried this experiment with beets at different periods of their growth. The experiments recorded were all made with mature beets, and the formation of sugar was going on slowly and would probably have proceeded slowly if the beets had remained in the ground with their full growth of leaves intact.

§ 73. The effect upon the coefficient of purity is quite as marked as upon the amount of sugar present. In one case, it is true, the coefficient of purity appears to have been lowered; this may really be the case, but I am inclined to consider it an accident, especially as the seven other experiments agree in showing an increase in the coefficient, while this one alone shows a decrease.

THE REDUCING POWER OF BEET CHIPS.

§ 74. Thinking that some light might be obtained on the preceding subject by determining the reducing power, shown by the beet pulp after the extraction of the sugars, reacting with alpha naphtol, by means of 80 per cent. alcohol, a series of experiments was made, in which the ground dried beets were extracted with

boiling 80 per cent. alcohol so long as the solution continued to react with alpha naphtol. I will observe, in passing, that this alcoholic extract yielded, after the alcohol had been distilled off, furfurol, upon distillation with hydrochloric acid of 1.06 sp. gr. The residue thus freed from sugar was boiled for thirty minutes in a flask provided with a reflux condenser, with 1.25 per cent. hydrochloric acid solution. The solution was made to volum, and its reducing power determined. No furfurol could be detected as escaping from the condenser. The results were as follows:

Kleinwanzlebener	9- 2-97—2.535 per cent. pentoses.
Kleinwanzlebener	9-22-97—3.415 per cent. pentoses.
Kleinwanzlebener	10-13-97—2.624 per cent. pentoses.
Vilmorin	10-13-97—3.445 per cent. pentoses.
Yellow Globe	10-29-97—2.673 per cent. pentoses.
Lane's Imperial	10-29-97—2.729 per cent. pentoses.
Zehringen	11-10-99—5.897 per cent. pentoses.
Vilmorin	11-10-99—5.615 per cent. pentoses.
Zehringen—after soaking	11-10-99—5.770 per cent. pentoses.
Vilmorin—after soaking	11-10-99—5.065 per cent. pentoses.

The total furfurol which the samples were capable of yielding was not determined.

§ 75. The two fodder beets, the Yellow Globe and the Lane's Imperial, were included to see whether they contained more or less of these pentose bodies than the sugar beets. In the Zehringen and Vilmorin samples of 1899, we observe that the reducing power of the extracted pulp is high. The sugar content is also high, but the table does not show a decrease in these substances as the beet matures; at best, it is not conclusive, because the series is not extended enough. But three out of four show a lower percentage for pentoses, accompanying a lower sugar percentage, and four out of five show a higher percentage, accompanying the higher sugar percentage. The two soaked samples agree in showing a decrease in the pentoses present, which may be due to transformation of these bodies into others. It seems probable that not only the monosaccharids, such as glucose, may suffer change into polysaccharids, but that the pentoses may also be involved in similar changes.

THE SUGARS IN BEET LEAVES.

§ 76. I have tried four methods in my efforts to prove the presence of sucrose in the leaves and to determine its quantity.

The first one tried was the investigation of the expressed juice of the leaves. This was very unsatisfactory, and led to no conclusion except that there is in the juice of the leaves one or more bodies which yield upon hydrolysis with hydrochloric acid bodies which reduce Fehling's solution, but I did not succeed in establishing the presence of sucrose by this method.

§ 77. The expressed juice of the leaves was subjected to fermentation and subsequent distillation. Two thousand seven hundred and forty-nine grams of juice, expressed from fresh leaves, stems and blades being used, received a quantity of compressed yeast and was allowed to stand 36 hours at a temperature of from 26° to 31° C., after which it was subjected to distillation. A blank test was made as a control. The results showed the probability of fermentable sugars in very small quantities in the juice of the leaves.

§ 78. A larger quantity, 30 pounds, of stems of leaves were gathered October 20, 1899, when the deposition of sugar was supposed to be active, dried quickly, ground, and subsequently extracted with 80 per cent. alcohol. The alcohol was distilled off and the extract concentrated, a little ammonia being added from time to time. The fluid extract was treated repeatedly with ether to remove the chlorophyll, etc.; an aliquot part of it was taken and treated with lead acetate, the sugars inverted by hydrochloric acid, determined by Fehling's solution and calculated as sucrose. The total sugars found corresponded to 0.28 per cent. calculated on the green stems. The inversion was quite difficult to effect, much more so than the inversion of pure solutions of cane sugar.

§ 79. The fourth method followed was that of Brown and Morris, *i. e.*, extraction with ether, and solution of sugars in alcohol; treatment with lead acetate, removal of lead; determination of glucose by means of Fehling's solution; inversion of maltose by means of invertin, and inversion of all of the invertible sugars by hydrochloric acid.

§ 80. A sample of leaves, Kleinwanzlebener variety, gathered September 2, 9 a. m., when the beets were growing vigorously, gave the following results:

Glucose	0.156 per cent.
Maltose	0.030 per cent.
Sucrose	0.000 per cent.
Total	0.186 per cent.

Kleinwanzlebener, leaves gathered September 22, 9 a. m.:

Glucose	0.801 per cent.
Maltose	0.023 per cent.
Sucrose	0.064 per cent.
Total	0.888 per cent.

Kleinwanzlebener, leaves gathered October 13, 10 a. m.:

Glucose	0.398	per cent.
Maltose	0.394	per cent.
Sucrose	Lost	per cent.
Total	0.792	per cent.

Vilmorin, leaves gathered October 13, 10 a. m.:

Glucose	0.398	per cent.
Maltose	0.186	per cent.
Sucrose	0.000	per cent.
Total	0.436	per cent.

These results agree in showing the presence of glucose and maltose, the latter being present in smaller quantity than the glucose, while cane sugar is present in subordinate quantities or absent.

As experiments show that the alcoholic extract of beet leaves yields furfurol when distilled with hydrochloric acid, indicating the presence of pentoses in this extract, which are susceptible of hydrolysis, it cannot be considered as rigorously proven that there is any cane sugar present, though the probability of its presence seems quite strong. But it is much less than has been found in the leaves of other plants which do not store sugar as a supply for the future use of the plant.

SUMMARY.

§ 81. The effect of the alkali is noticeable, but to a less extent than in 1897, and the area in which its effects appear are more restricted.

The application of straw, as well as of manure, improved the condition of the ground and perceptibly mitigated the effects of the alkali.

The application of manure improved the stand of beets, but did not prevent a failure to germinate in some spots.

The amount of water received by the crop of 1898, rain and irrigation water together, was about eight inches.

The water plane varied from three to six feet below the surface in different portions of the patch at various times during the season.

The force of capillarity caused water to rise 45 inches as a maximum, the surface of the soil being protected from wind and sun.

The plot receives subirrigation, though there is a drain and an open ditch, supposed to intercept this water.

The cultivation in 1897 differed in one respect from that given in 1898 and 1899. In 1897 the crop received two irrigations and more cultivations than in the latter years. The soil was kept more mellow. In 1899 it was purposely firmed about the beets in September, and no effort was made to mellow it after this. The percentage of sugar in 1898 and 1899 was higher than in 1897. This was in part caused by the condition of the soil produced in 1899 by intentional over-irrigation.

The effects of the manure upon the crop was to produce ill shaped, rooty beets, also to slightly lower the percentage of sugar and the coefficient of purity. Its effect on the shape of the beets was far more serious than that on the percentage of sugar and coefficient of purity.

The conclusion reached in 1897, relative to the effect of the alkalized condition of the soil upon the percentage of sugar in the

crop, is corroborated by the observations of the years 1898 and 1899, *i. e.*, that the alkali *per se* is not injurious in such quantities as it is present in any part of our plot.

The effect of the manure upon the shape of the beets was noticeable the second season after its application, but it was less marked than it was the first season. But its effect upon the percentage of sugar and the coefficient of purity was almost as marked the second year after its application as it was the first year. The peculiar soil conditions are in part the cause of this, for they retard the rotting and complete incorporation of the manure with the soil.

The marked increase in the percentage of sugar at the period of ripening, observed in 1897, was not observed in the years 1898 and 1899. The difference in the manner of maturing is attributed to the difference in the seasons. It is possible, though not probable, that such increase had already taken place before we took our first samples, September 27. The beets did not show any signs of having ripened at this time.

The beets from the Farm plots and our alkali ground showed no difference in this respect, corroborating the observation of 1897, that the alkali was without influence on the maturing of the beet.

Cut straw was applied to one section in order to compare its effects with those of the manure, as a measure of the extent to which the manure might act as a mechanical agent. It benefited the soil greatly, its mechanical effect being nearly as great as that of the manure, but the effects of the manure were in other respects much greater.

The percentage of dry matter in the beets of the years 1898 and 1899 was higher than in 1897, due, probably, to seasonal differences. The average difference for beets from my plot was 4.9 per cent. in 1898 and 3.8 per cent. in 1899.

The average percentage of sugar in the crop for 1898 was, after making allowance for some drying out of the samples, 13.62 per cent. The average of the crop grown on alkali soil was 13.65 per cent.

Medium sized beets are apt to be better than either large or small beets, but the size is less determinative of the quality of the beets than the conditions under which they grow. Beets weighing two pounds and upwards are quite as rich as those weighing less than one pound, if they have been grown under the same conditions.

The effect of excessive free space was studied on a row planted singly, with unoccupied ground for several feet on either side. The beets were very close to one another in the row. The average percentage of sugar was lower than shown by the same varieties grown in rows twenty inches apart.

Over irrigation applied at the proper time, produces, in some soils, an increase in the percentage of sugar, without materially, if at all, decreasing the crop.

The continued cropping and cultivation of our plot has slightly decreased the percentage of ash in the beet and changed its composition, particularly lowering the percentage of chlorin.

If fresh beets be soaked for seven days in water cooled by ice, an actual increase of sugar takes place, indicating the formation of sugar in the beet root.

The substances in beet chips hydrolized by dilute hydrochloric acid, are, as a rule, higher in beets rich in sugar than in stock beets, or in those having a lower percentage of sugar.

The leaves of the sugar beet contain some glucose and maltose, but only small quantities, if any, sucrose.

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The Agricultural Experiment Station

OF THE

Agricultural College of Colorado.

INVESTIGATION OF THE GREAT PLAINS.

FIELD NOTES

—FROM—

TRIPS IN EASTERN COLORADO.

—BY—

J. E. PAYNE.

PUBLISHED BY THE EXPERIMENT STATION
Fort Collins, Colorado.
1900.

THE AGRICULTURAL EXPERIMENT STATION,

FORT COLLINS, COLORADO.

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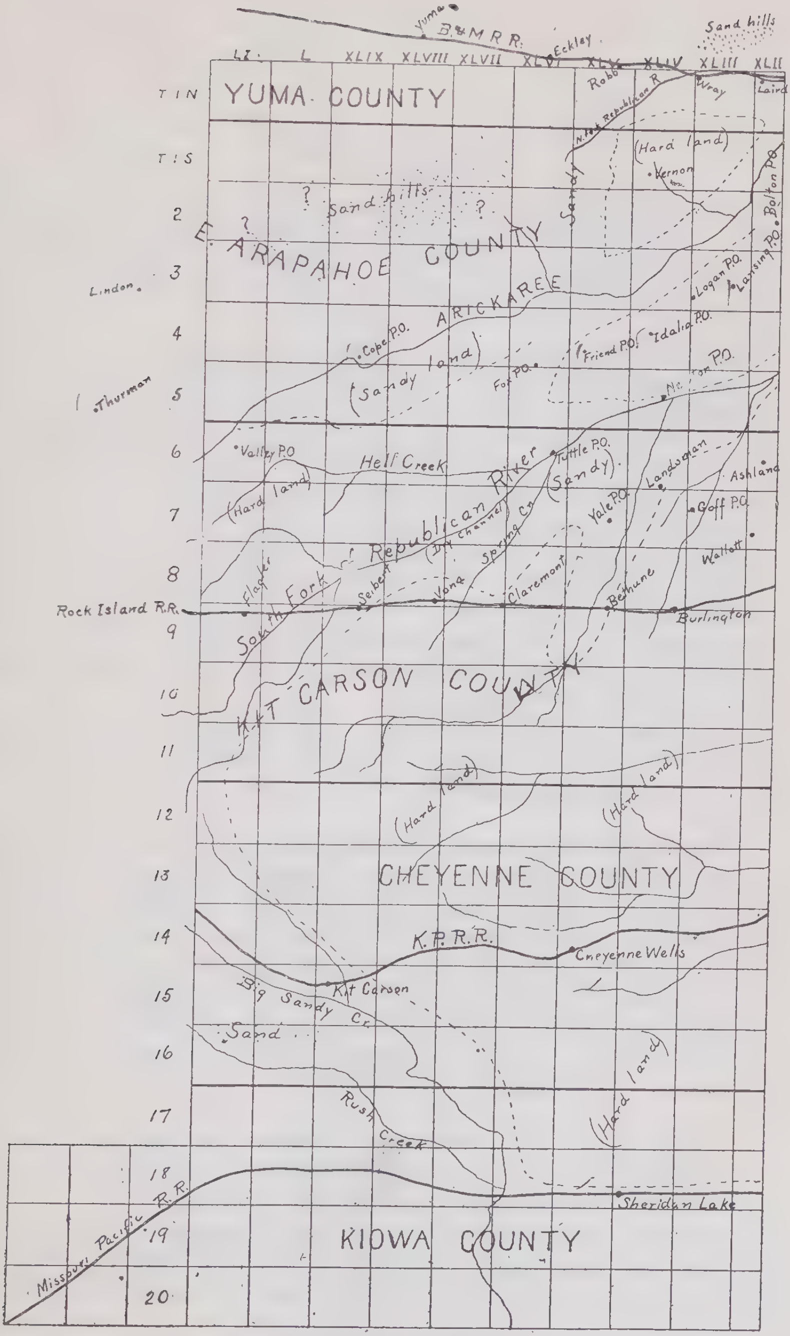

MAP OF REGION EXAMINED.

INTRODUCTORY.

Some years since (in 1894), a substation was organized at Cheyenne Wells, in Eastern Colorado, for the purpose of testing plants and methods adapted to that region. A report of the trials was given in the Annual Report for 1899. *

During the past year a different plan of work was adopted, both because it seemed that greater results could be secured, and because the authorities at Washington had ruled that the maintenance of permanent substations was not contemplated by the Hatch Act. The work was lessened so that the superintendent had fewer duties at the station; he was furnished with a team, and his time largely given to a study of the methods of those who have gained a foothold, and to derive therefrom lessons of greater value than could come from the tests of a single person. The work of the year has been preliminary, but was necessary to establish a sound basis for future investigation or discussion of the problems of the Plains.

The reconnaisance covers only a small part of the Plains portion of the State, and, therefore, the statements are not necessarily true for the region outside that considered.

The Plains portion of Colorado extends from the eastern border of the State to the foothills of the Rockies. Fort Collins, Boulder, Golden, Colorado Springs, Florence and Trinidad are at or near the western border. Along the eastern border the elevation is from 3,500 to 4,500 feet, and along the foothills from 5,000 to 7,000 feet, the latter elevation being found on the Divide between the Platte and the Arkansas rivers. The Plains are thus an inclined plane, rising almost imperceptibly from ten to twenty feet per mile.

Limitless in expanse, with scanty, though nutritious, grasses, the Plains form the natural home of the stock industry, as they once did of vast herds of buffalo.

This is not the place to discuss the Plains problem. With an area greater than most of the states east of the Mississippi, the magnitude of the area justifies a serious examination.

L. G. C.

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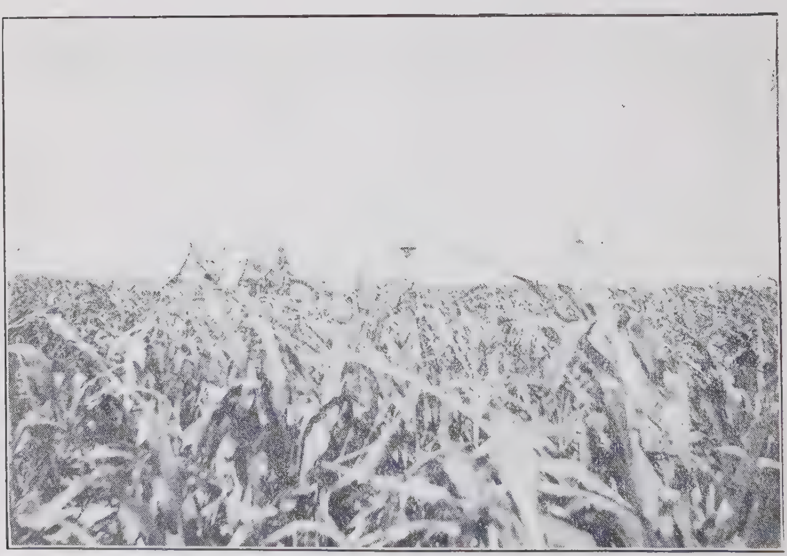
* Also issued as an excerpt.

SORGHUM ON OLD GROUND.



SORGHUM ON SOD.
(Same row, planted same day as preceding.)

INVESTIGATION OF THE GREAT PLAINS.

FIELD NOTES

—FROM—

TRIPS IN EASTERN COLORADO.

By J. E. PAYNE, M. S.

Superintendent of the Plains Substation.

This work was done by traveling about the country in a spring wagon. Over thirteen hundred miles were traveled during the progress of the work. Settlers were interviewed, and their evidence recorded. The investigation was confined mainly to Kit Carson county and the eastern half of Arapahoe county.

Contrary to my rule, I have recorded my opinions and impressions in this report. These opinions are based upon a mass of evidence which is almost too extensive to record.

With the exception of small areas near Idalia, and Vernon, stock raising is the principal business of the people. Those having small herds usually raise some rough feed for use during storms. The Vernon settlement seems to be the only one which has held its own and held to the idea of grain raising exclusively. Many near Vernon believe in stock raising, but the country is occupied so fully that there is no range for stock. At Vernon, and near Lansing, Idalia and Friend, sentiment has made a local herd law which persuades each man to fence or herd his stock during the growing season. In all other communities, crops must be fenced to protect the cattle, but in those neighborhoods, the saying has become proverbial that, "No one has ever known a wheat field to chase cattle to their injury." So if a man keeps stock, he must keep it away from his neighbor's crops. These people, living from one hundred and thirty to one hundred and fifty miles from their county seat, do not often feel the force or effect of ordinary State laws; so they have been forced to allow a few customs suited to their conditions to crystallize into laws, so far as it is possible in the time they have lived in these communities.

Depopulation—Almost the whole of Eastern Colorado was settled quite thickly during the years from 1886 to 1889. Lansing, Idalia, Friend, Cope, Arickaree City, Thurman,

Lindon and Harrisburg all aspired to be large cities, county seats or railroad centers. Lansing has disappeared and left only a few cellars to mark its site. Idalia still has two stores, two blacksmith shops, a school house and a few dwellings. At Friend, one old building, now used for the school, remains. Cope still has a store, a few dwellings and a school. One store building (now used as a residence by a family of four) still stands on the site of Arickaree city, and Arickaree P. O. is located on a ranch eight miles away. About Lindon, nearly all the land for miles around was once filed upon. Failure to get water in necessary quantities caused the whole country to be depopulated. At one place, I drove eighteen miles between Cope and Lindon without seeing a house. The site of old Lindon is now marked by a few heaps of earth and a few holes in the ground. Lindon postoffice is four miles south-west of the old town site, and the nearest house is two miles away. At Harrisburg, one family still lives. Thurman, also called Stone city, once had two banks, and two railroads were surveyed through it during "boom times." Now one family lives in Thurman. But a colony of hardy Mennonite farmers still hold claims near enough together to make lanes necessary. Two lanes cross at Thurman postoffice. These farmers are all getting to be quite well-to-do. They make stock raising their main business, but they usually raise grain, and always produce plenty of rough forage for their cattle. By these people, the Russian thistle is considered a friend. If the wheat crop fails, the Russian thistle grows among the wheat, and Russian thistle and wheat mixed make excellent feed. Before the introduction of the Russian thistle, they had no winter forage when their wheat crop failed.

TREES—*Timber Claims.*

Of the thousands of claims planted to trees, only a few groves remain to-day in thrifty condition. I made it a point to visit every grove which was said to be in good condition and still cared for.

Observation has shown that groves cease to do well as soon as they are abandoned and permitted to become scratching places for cattle. After inspecting several hundred claims, we decided that the trees which have been able to withstand the conditions best are ash, honey locust and black locust. I photographed two of the best groves I saw. One of these is one-half mile west of Logan post office. The other is seven miles north-east of Lansing post office.

These have both been thinned to eight feet apart each way. They are nearly all ash trees. The tallest tree in each grove is an elm. The grove north of Lansing is on a high divide, while the one near Logan is on flat land where it may get some extra water.

There are many other places where small groves are still kept in good condition. Near Thurman, Mr. Joseph Schrock has a row of ash trees near his corrals which measure from thirteen to twenty-nine inches in circumference. These are planted where the snow piles up around them every winter. At the same place, a cottonwood tree growing near a water tank is kept in a thrifty condition by the waste water.

One of the most widely known of the groves on high prairie is that of Success Kerns who lives three miles northeast of Claremont. Intensive cultivation has been practiced, and no irrigation. Mr. S. L. Howell, near Vona, has raised some nice groves on the high prairie.

I have taken records of many other groves, but these are the ones that seem most likely to receive continuous care.

Of the trees growing where water is near the surface, Cope's grove, at Cope, on the Arickaree bottom, presents the best example. About twenty acres were planted to trees there during the years 1887—1890. Cottonwood, boxelder and ash are the principal varieties, between five and six acres of trees still remaining. The best part of the grove is cottonwood trees which grow where water is from two to five feet below the surface. Many of these are forty to fifty feet high, and some are three feet in circumference.

TREES—*Miscellaneous.*

The best example of how one may use the natural conditions, as slopes, ravines, and so on, to help trees and crops is found at the place of James Howell, who lives seven miles northeast of Flagler. The forest trees which are mainly black locusts are set in clumps and hedges so as to make a dense windbreak. The orchard is on the right bank of a creek which runs southeast. A well at the southeast corner of the orchard, supplemented by a small storm-water reservoir at the northwest corner, supplies water for irrigating, in a small way, where need is greatest. The ravine has been dammed and the extra water conducted past the grove through an artificial channel, leaving the old channel dry below a pond of water which at times is several feet deep.

The sides and bottom of this old creek bed were recently planted to fruit trees—mostly cherry trees. On one bank stand several plum, cherry and walnut trees which have reached the bearing age. Just above each of the trees on the bank is a large hole into which water from higher levels may flow during rains. The walnut and cherry trees bore good crops in 1900. Some apples were seen on the apple trees. The grapes, strawberries and currants also showed fair crops.

FRUIT TREES—*Not Irrigated.*

When the country was first settled, hundreds of orchards were set out. Lack of skill, bad nursery stock and drought reduced the number of orchards to one here and there where a combination of circumstances kept alive the hope that a successful orchard could be produced.

Many orchards were kept in good condition until 1893 at which time they were about five years old. The unfavorable conditions of 1893, 1894 and 1895 reduced the number of experimenters to a few, who were as stubborn as Colorado droughts. One of the best orchards given up in 1894 was that of A. C. Willis, three miles north-west of Kanarado. For a time, he had the best trees in the county, but dry weather and hail damaged his trees so badly that he became discouraged.

The following table gives a summary of the present condition of orchards on uplands, or where it is impossible to get sufficient water for irrigation. I include James Howell's place in this because he has made his success by taking advantage of natural conditions, just as hundreds of others could do if they would use the same amount of thought and labor.

It is generally conceded that cherries, currants, plums and gooseberries can be produced in moderate quantities without irrigation. Apples and peaches are not considered sure although some have been produced.

Owner.	*P. O. Address*	*Trees still thrifty.*				*Trees which have produced fruit*			
R. F. Davis,	Vernon,	Apples,	peaches,	plums,	cherries.	Apples,	peaches,	plums,	cherries.
James Slick,	"	"	——	"	"	"	——	"	"
W. S. Calloway,	"	"	——	"	"	"	——	"	"
Joseph Miller,	"	"	——	——	——	"	——	——	——
Allan Smith,	Wray,	"	——	plums,	cherries,	"	——	plums,	cherries.
Wm. M. Barnes,	Jaqua, Kan.,	"	peaches,	"	"	"	peaches,	"	"
J. Brigham,	" "	"	"	"	"	"	"	"	"
S. L. Howell,	Seibert, Colo.,	"	"	"	"	"	"	"	"
James Howell.	Flagler, "	"	"	"	"	"	"	"	"
P. J. Nicholls,	Cope, "	"	——	"	"	"	——	"	"
W. J. Brooker,	Cheyenne Wells,	"	——	"	"	——	——	——	——
The Plains Substation,	" "	"	peaches,	"	"	Apples,	——	plums,	cherries.
J. S. Johnson,	" "	"	——	"	"	——	——	"	"
J. B. Robertson,	" "	——	——	——	——	Apples,	——	plums,	——

Gooseberries and wild currants generally do well with-

out irrigation. I found grapes bearing at Peter J. Nicholls' garden and also at Joseph Schrock's. Grapes found in bearing at James Howell's place had received some extra water.

Ornamental Plants—We have found roses doing well without irrigation at several places.

IRRIGATED PLACES.

John Rose, who lives five miles northwest of Seibert, has been the most successful with a fruit garden of any one we have seen. He began by irrigating only a few trees and a few rods of garden. He extended the plat to include about one fifth of an acre which was watered from one well. The water was pumped by wind power from a well eighteen feet deep. Later, he dug another well and built a reservoir and extended his patch so as to include nearly two acres. We attribute his success to his ability to begin on a small scale and slowly enlarge as he learned how to handle his water economically, and as he found profitable market for his products. We shall file photographs* of an apple tree and a plum tree as they appeared in his orchard in September 1900, also a photo of his reservoir. Charles Blake and James H. Priest who live in the same neighborhood are making a success of their irrigated fruit gardens also. All raise apples, plums, cherries, gooseberries, currants and strawberries. Mr. J. C. Cope, at Cope, has a good fruit garden which is irrigated from a well.

But the most successful irrigation where deep wells are used, is that of Peter Eckert who lives about four miles southeast of Thurman. His two wells are each one hundred and twelve feet deep. The water is pumped by windmills into reservoirs for storage. The pumps run day and night to water about two acres and supply water for a large herd of cattle. The place is located on a hill. All the ground irrigated is nicely terraced so as to use the water to the best advantage. One part of the place is laid out for ornamental plants and a vegetable garden, another for fruit trees, excluding apples, another is the apple orchard, and the other is planted to grape vines. Hail and wind has prevented the production of much fruit of any kind. But the place is well kept notwithstanding the fact that it does not give large financial returns. The owner loves his trees and vines as he does children. He is too feeble to work in the field, so he spends nearly all his time with his trees and his garden.

A few who live around the south fork of the Republican

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* Not suitable for reproduction.

or its tributaries, water their trees and gardens from ditches. Among the most successful of these are G. B. Kuk and Wm. P. Baily near Newton, and C. Waline who lives about five miles southwest of Jaqua. Mr. Waline uses a storage reservoir in connection with his ditch. He also uses a well to help out in times of scarcity.

Those who are using windmill power to pump water for the irrigation of vegetables are too numerous to mention, but the really successful plants are few. The main trouble is that they usually attempt to do too much—spread over such a large area that when crops are most in need of water the supply is insufficient.

I saw one place where a man had built a reservoir and planned to irrigate five acres of very sandy land from one well. When the supply of water is sufficient we sometimes find that insufficient reservoir space is another weak point. The wind may refuse to blow during the dryest weather of the summer, and when it does blow, the water is often applied to the crops just as it comes from the well. This chills the roots and checks growth.

But the cause of the abandonment of many successful small irrigation plants has been the increase of the herd of cattle kept to be watered from the same well upon which the garden was dependent for its supply.

Storm Water from the Prairies—Mr. W. V. Erickson, who lives three miles southeast of Burlington, is one of the most successful of those who have watered gardens from wells. He has planned to catch the storm water from several hundred acres of prairie in a reservoir which he was making when I visited him. We shall watch the result of his work with interest. Mr. James Howell, near Flagler, who was mentioned before in the discussion of trees, has the only storm-water reservoir which we saw in operation. His main reservoir would be likely to benefit his trees mainly by the seepage of water down the old creek bed, thus furnishing natural sub-irrigation.

IRRIGATION DITCHES.

There are two ditches in the valley of the South fork of the Republican river. These were planned to supply water to large areas; but they seem to be failures. Small ditches water considerable areas planted to alfalfa near Tuttle, Landsman and Newton. A few small private ditches are successfully operated on the lower part of the Arickaree. One very successful ditch is operated in the valley of the North fork of the Republican.

UPLAND FARMING.

In every community through which I have traveled, except small areas near Idalia and Vernon, stock raising is considered the principal part of farming. Other communities are in various stages of transition from grain to stock raising.

Cheyenne County—All given over to stock raising and practically no grain raising attempted.

Kit Carson County—I divide into districts as follows:

1. All south of the Rock Island railroad and nearly all west of Claremont given over to stock with but little grain raising.

2. Yale, Wallet, Goff, Ashland and Burlington—Stock raising is considered first by practically all the settlers. But some plant grain hoping to harvest a crop if the season is favorable; but if the season is unfavorable, they expect a crop of forage from the grain fields.

3. Valleys of the Landsman and South fork of the Republican—Nearly all occupied by stock men before the wave of settlement came. Still given up to stock exclusively, except a few places near Seibert where men have obtained a foothold and are developing horticulture on a small scale. Alfalfa-growing is quite general wherever there is water enough for irrigation.

Eastern Arapahoe Couuty:

1. Lindon—Given up to stock exclusively.

2. Thurman—Grain is sown quite extensively. There is some threshing done nearly every year. When the season is unfavorable for wheat, it is a good season for Russian thistles. The wheat and thistles are cut for hay, and make good feed when used together.

3. Kirk and Fox—On the border line between a stock raising district and a grain-growing district. Here we find that nearly all are still raising grain; but all are getting into the stock raising business as rapidly as their means will permit.

4. Friend, Idalia, Logan, Lansing and Bolton—This district is devoted to grain growing. But there is a strong sentiment in favor of stock raising exclusively wherever large areas are available for free range.

5. Vernon—This district is devoted to grain growing. Some people own cattle which are kept in the sand hills during summer and brought in to winter around the straw stacks. Many around the edges of this settlement favor stock raising exclusively.

6. The Sandhills in Eastern Arapahoe—This district is devoted to stock grazing exclusively.

7. The valleys of the Arickaree and the South fork of the Republican river are devoted to stock raising exclusively.

Yuma County—That part of Yuma county lying on the divide between the north fork of the Republican and the Arickaree belongs with the Vernon neighborhood. The valley of the North fork of the Republican is used mainly for stock raising. The fields of alfalfa furnish winter feed for cattle which are kept in the sandhills on the north of the valley.

CROPS RAISED.

Sorghum—Generally grown where stock raising is the main business. Many cattle men object to it on account of the heavy work required to harvest it. Yield from one-half to four tons per acre. Average probably one ton per acre.

Broom Corn—Usually successfully raised. Uncertainty of price has prevented extensive planting.

Millet—Quite a general favorite among cattle men. They claim that it requires less exertion per ton to raise and harvest millet than any other cultivated crop. Yield from one-fifth to two tons per acre.

Corn—Corn is generally planted in small areas in nearly all neighborhoods investigated. Many claim that if the season is favorable, corn can be raised cheaper than it can be bought. But if the season is unfavorable, a crop of fodder will be raised. The average yield is best on black, sandy land. Yields as high as fifty bushels per acre have been reported. The usual yield is from two to twenty-five bushels, while the average for the whole region will not exceed ten bushels per acre.

Oats—Usually considered an uncertain crop. Less popular than wheat or millet. Considerable is sown for hay in some places. Reported yield per acre from nothing to thirty-five bushels. Probably the average is near ten bushels per acre.

Wheat—The most popular of small grains. Reported yields from nothing to forty bushels per acre. The general average yield per acre for the region is probably about six bushels. Some have reported average yields of eleven bushels per acre, including twelve years cropping. From observation, I believe the men who produced these crops to be far above the average as farmers, and so cut down my estimate of the average yield accordingly.

Barley—A crop which is but little grown, as compared with wheat. Many consider it the surest grain crop that has

GROVE OF MILTON MORRIS, NEAR LANSING.

GROVE OF HUGO KURZIDIM, NEAR LOGAN
(Tallest tree in each case is an Elm.)

been tried. Yields of eighty-three bushels per acre have been reported. The average yield is estimated at fifteen bushels per acre. The variety planted is mostly "California Feed" barley, and it is used at home for feed almost exclusively.

Rye—This crop is but little grown. Not enough found upon which to base an estimate. But, in 1899, a crop was grown on a field of black sandy soil near Cope which yielded seventeen bushels per acre. No rain fell upon this field between seeding and harvesting.

Flax—We have found men near Ashland and Thurman who have raised good crops of flax. So few raised it that what was raised was not readily sold, so production ceased. It has not been generally tried.

Native Hay—The valleys of the North branch of the Smoky Hill river, the three valleys of the Republican, the valley of the Big Sandy, and the Sand hills furnish considerable native hay every year. We made no attempt to make a collection of native hay plants this year. Hay is usually cut about two years in every five on the uplands. This consists mainly of several species of grama grass and Colorado bluestem (which is known also as bluegrass, elk grass, June grass and probably by several other names.) In traveling over the county, I noted that Colorado bluestem is taking posession of land which has been broken, and abandoned. It appears to successfully dispute the right of occupancy with the Russian thistle. We have also seen it invading uncultivated timber claims and growing quite rank among the trees.

Russian Thistles—Russian thistles are quite common in all the regions studied except in about two townships near Idalia and five near Vernon. Wherever the Russian thistle has obtained what seems to be a permanent foothold, the settlers are using it quite largely for forage. Thousands of tons of it are now stacked up for use during the winter. We issued a press bulletin concerning "The Russian Thistle as a Forage Plant," in July, 1900. This bulletin was widely quoted.

Salt Weed—(Atriplex, sp?) This plant is found on the upper part of the South fork of the Republican as far down as Seibert, and in the western half of Cheyenne county. It seems to prefer an adobe soil containing considerable alkali. The stock that range where it grows do not eat salt, as they get enough salt to supply their needs by occasionally taking a bite of salt weed.

Wm. Lang, who lives near Cheyenne Wells, made hay

of "salt weed" several years ago. He reports that his sheep did well on it. Last year, a cattle man on the South fork of the Republican put up some for hay. He reports good results. September 22nd., 1900, I photographed a rick of salt weed one hundred and twenty feet long. This was put up by Mr. Thos. McCallum who lives ten miles south of Arriba. He intends to give it a thorough trial this year.

SOIL STUDY.

As I traveled I examined the soil by occasionally boring and noting the appearance of the soil and sub-soil.

A traveler could go from Sheridan Lake in Kiowa county to Wray in Yuma county (one hundred and ten miles) and think he was traveling over the same kind of soil all the way, except short stretches on each side of the larger streams. The whole distance traversed would be on practically the same kind of soil which is known locally as "hard land." It has enough clay in it to make a good road bed. This land sustains a growth of the short grasses—as buffalo grass and grama grass. Along the streams is found a sandy soil upon which sage brush is the principal vegetation.

This "hard land" is the principal type found on all the uplands of the region investigated. Between this upland soil and the valleys is usually a strip of sandy soil which may be from a few feet to several miles in width. The river valleys proper frequently have an "adobe" upon which "alkali grass" grows. Usually where "alkali grass" does not grow the soil is too sandy for profitable cultivation. The sandy soil is usually considered best for corn, while the "hard land" is thought to be best for wheat.

METHODS OF PLANTING AND CULTURE.

Corn and Sorghum—The lister drill is generally used for planting corn and sorghum. After planting, the harrow is used by many until the plants are so high that the harrow may break them down if used. Weeders are coming into use also. We find many who advocate frequent culture to preserve a "dirt mulch" on the top. This is supposed to require stirring the ground after each rain, and occasionally during prolonged droughts. But many object to doing this because it requires too much labor.

Observations made during this year have confirmed my belief in the value of a "dust mulch," but I am also convinced that the "dust mulch" may be just as valuable when covered by a light crust such as is formed by a light rain as when no

crust is allowed to form. I saw dust blankets on prairie where no tool had ever tickled the earth.

Once, when crossing a sandy stretch of country, I saw some fields of corn which were looking healthy, notwithstanding the fact that no rain had fallen for several weeks. The corn had not been cultivated for at least a month; so I examined the soil in the corn. I found a light crust, then a dust mulch from two to three inches thick and below that, moist soil. I then turned to the unbroken prairie and found practically the same conditions. I afterwards examined dozens of cornfields and found the same conditions wherever the cultivation had been thoroughly done, even if it had been several weeks since the soil had been stirred.

Millet—Methods of planting differ widely. Practically all seeding is done broadcast. Some plow shallow, some do not plow at all, but broadcast the seed and cover with the disc harrow afterwards. Results reported to be about the same from all methods.

Small Grain—It is generally agreed that small grain does best when sown on ground which has been cultivated the year before in some hoed crop. The most generally used method is to broadcast the seed on unprepared land (not plowed or disced but the sod broken, of course) and cover with disc harrow or cultivator. Some use disc press drills and some use the other kind of drills. There are men who hold to each of the methods.

Some claim that they have always harvested heavy crops when enough rain fell at the right time, no matter how the grain was put in; and that they never got anything when the season was against them no matter what method they had used.

Pests—The two pests which do the most damage to crops in the region investigated are potato beetles (*Meloidae*) and grasshoppers. There are few years when the settlers could not raise enough potatoes to supply the local markets if the crop could be protected from the potato beetles and grasshoppers.

In 1896, one man had to move his cattle to another range on account of the ravages of a variety of grasshopper which ate grass exclusively. This year I saw many fields of grain which were badly damaged by grasshoppers. They reduced the yield harvested, by cutting the heads off the wheat and oats before the grain was ripe enough to cut.

CONCLUDING OBSERVATIONS.

Natural conditions seem to have fitted this region for a

grazing country, but the hardships encountered by people in gaining a living in the crowded eastern states have pushed people into what the cow-man once thought his exclusive domain. After settlers got in, many found that, hard as conditions were on the plains, they could do better here than they could with the same capital in any other place with which they were acquainted. These men have built themselves homes, and, in a measure, made the nomadic life of the old-time cow-boy an impossibility in the future.

Nearly all the settlers have been compelled to turn their attention to stock raising, on account of crop failures during some years and low prices other years. The main drawback to grain raising in the region near Idalia is the distance from market. All wheat raised on that divide must be hauled in wagons from thirty to forty miles. Considering these factors, almost any business farmer would decide to raise crops which could walk to market, or crops which could be condensed. And nearly all who live there believe in doing this, even if they do not practice it.

At present, on account of the demand for beef cattle and the confining work connected with dairying, only a small amount of butter is produced. But when the price of cattle goes down again the same natural business law which has forced people to go into cattle raising will compel them to turn their attention to the production of butter and cheese. Free range, cheap rough feed and inexpensive warm stables will help them to make winter dairying profitable. When they get to this, all products will be sent to market in condensed form, and the importance of the problem of transportation will be reduced. The country can then support sufficient population to supply good schools for the children. Each family can have a small garden, a few fruit trees and some small fruit for home use. These can be irrigated from a well. Natural conditions, such as are used by Mr. James Howell, will probably be taken advantage of more freely than at present. People who are either unwilling or unable to adapt themselves to the new conditions will move away, and their places will be taken by others who are better adapted to the conditions.

The valleys of the Big Sandy, the South fork of the Republican and the Arickaree may some day support quite a population. Much of the land near these streams is too sandy for profitable farming. But, if those streams were turned out of their courses and the water taken out into the uplands, and the storm water stored in reservoirs, large bodies of good land might be irrigated and hundreds of homes maintained in what is now merely a cattle pasture.

Bulletin 60. December, 1900.

The Agricultural Experiment Station

OF THE

Agricultural College of Colorado.

BUSH FRUITS,

INCLUDING

GOOSEBERRIES, RASPBERRIES, BLACKBERRIES, DEWBERRIES.

—BY—

CARL H. POTTER.

PUBLISHED BY THE EXPERIMENT STATION
Fort Collins, Colorado.
1900.

THE AGRICULTURAL EXPERIMENT STATION,

FORT COLLINS, COLORADO.

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A VARIETY TEST AND GENERAL REMARKS

—ON—

BUSH FRUITS.

CARL H. POTTER.

GENERAL REMARKS.

It is not the intention in issuing the present bulletin to go deeply into a consideration of the culture and general management of bush-fruit plantations. This information comes to the practical growers from many sources.

Good and abundant cultivation and irrigation is of prime importance. A naturally cool and somewhat moist soil is desirable, and in the hotter portions of the State a partial shade is often necessary. This shade is sometimes obtained by planting the bushes near shade trees, or even in orchards, but this latter practice is not always looked upon with favor by our best orchardists. Again, simple mulching is used.

The rows should be placed at a liberal distance apart and the hills should not be crowded in the rows. A few good, vigorous shoots should be grown, thus better to resist the ravages of the increasing number of our insect and disease enemies.

Prof. Gillette, in Bulletin No. 47 of this station, names five or six insect enemies which are injurious to our bush fruits. Of these, perhaps the worst two are the currant-borer, *Sesia tipuliformis*, and the saw-fly, *Pristophora grossulariæ*. The former is easily removed and destroyed by the usual annual pruning, thinning and burning of the old canes. The larvæ of the saw-fly are easily destroyed by the common arsenical sprays.

The ravages of the fruit-worm will be spoken of in connection with the fruits injured.

Diseases of the plants have but recently become of economic importance on our grounds. They will furnish material for future study and publication.

Our present plantations of bush fruits contain about

seventy varieties. A few varieties disappeared from the test-plats during the last three years, other varieties planted failed to become established, and still others were planted only last spring.

The older plantation was set in 1896. Other plants and other varieties were added in 1897 and in 1898, and a new plantation set in 1900. In so far as the blackberries and raspberries are concerned, these latter years enter comparatively little into the description or tests of plants or fruit which follow. The season of 1898 was so extremely dry that the water for irrigation purposes was entirely inadequate to the development of either fruit or vine.

This season of drought was followed by the extremely early and severe winter of 1898-9 which prevented the proper covering of the vines, resulting in the complete killing to the ground of all the raspberry and blackberry canes, thus preventing a crop in 1899.

The canes of all the raspberry and blackberry vines were pinched back when about 18 inches in height, the result being a fine growth of well-matured stocky canes. They were laid down by removing the earth from underneath one side of the hill and forcing the tops in that direction with a fork, then covering to a depth of about 3 inches with earth. By a yearly practice of this method the roots extend laterally and are but little injured in the process of laying down, while the canes, though stiff and stout, are but little bent and are therefore uninjured.

Winter protection is the only safe course to follow in this section of the state.

GOOSEBERRIES--*Ribes.*

Even some of the currants and gooseberries suffered more or less severely by the extreme winter of 1898-9. A record of this injury follows in the notes on the individual varieties.

The gooseberry plantation consisted of six varieties, one of which, Industry, is now extinct. As there has been such a great difference in the age and vigor of the several varieties, it is thought best for the present not to append figures giving the comparative yields.

Three varieties new to the plantation were added last spring.

The gooseberry crop of 1900 was, from a commercial standpoint, almost totally destroyed by the ravages of the fruit worm, known to science as *Epochrox Canadensis.* The "worms" are the larvæ of a two-winged fly which deposits

its eggs underneath the skin of the fruit while the latter is still quite immature. Within the fruit, where they are quite safe from insecticides of all kinds, the larvæ grow to maturity. The fruit becomes worthless. The only known remedy is to destroy the fruit while it still contains the larvæ.

Following are the varieties tested:

Downing—*Ribes cynosbati.*

Some old bushes were reset in 1896 and some young ones in 1898. The bushes are upright in growth with stiff stocky branches, spines stout and prominent, berries medium to large with a conic, dark green apex, and covered with a heavy glaucous coat. Yield good. The variety was very severely killed back by the cold winter. All the hills, old and young, are looking remarkably vigorous now.

Houghton—*R. hirtellum.*

Of this variety some old bushes were reset in 1896, to which were added new bushes from the nursery the same year.

The variety is a vigorous grower with long, slender, spreading branches, spines slender, berries small to medium, surface glaucous, obconic form, deep green color, very sour, yield very good—fully a week later than the other varieties in the plat.

The old canes are fairly stocky and well loaded with fruit buds, but the variety is not nearly so strong and vigorous a grower as is Oregon Champion. Very little injured by the cold winter.

Industry—*R. grossularia.*

Young plants of this variety were set in 1896, to which were added some old bushes reset the same spring. The variety is of European origin. The leaves are dark green, leathery, with a lustrous surface. The thorns are short and stout and frequently there is but one at the base of each leaf-stalk instead of the usual cluster of two or three. The berries are large, oval, veins conspicuous, with a considerable number of bristles on the surface. The variety entirely succumbed to the mild winters of '96-7 and '97-8.

Oregon Champion—*R. grossularia.*

New plants of this variety were set in 1896. The variety is of spreading habit with rather large, stiff and stocky branches. The leaves are somewhat more glaucous and darker green than are the leaves of other varieties. The berry is large, oval, with a glaucous surface. The variety was apparently very little injured by the excessively cold winter of '99 and bore an excellent crop of fruit the next season. It is a most desirable variety on account of the vigor of the plants and the yield of fruit.

Pearl—*R. grossularia.*

Young plants of this variety were set in the plat in 1897. They made a good healthy growth during that and the following season. The winter of 1899 killed the canes to the ground and they were cut out. The growth the past two seasons consists of many vigorous and well branched canes.

Smith's Improved—*R. grossularia.*

Old bushes of this variety were reset in 1896. The variety is fairly vigorous and was not entirely killed back by the winter of 1899. It was severely pruned and made a fair growth during the past two seasons. Berries very large—largest on the grounds—quality good to excellent; long, oval form. Translucent, with conspicuous lighter-colored veins.

CURRANTS—*Ribes.*

The station plantation of currants consists of eighteen varieties, fifteen of which belong to the species *rubrum*, one Dubett Tree being *Ribes aurium* and two *Ribes nigrum*. The latter with four varieties of *rubrum* were set only last spring.

The red sorts are for the most part very similar, it being quite difficult to distinguish between them either by their fruit or the character of the plants. Where old bunchy varieties were set along with those trained to more of a tree form, the latter invariably produced larger fruit, but not so large a yield. The more abundant the fruit, the smaller the berries. The crop of fruit was, commercially speaking, a complete failure the past season owing to the ravages of the insect mentioned in connection with gooseberries. Much of the fruit fell before time for picking. Of that which remained on the bushes till the sound fruit was mature, from 25 to 60 per cent was stung and contained the larvæ of the fly. No such extensive damage appears on our previous records. Some plantations in this vicinity were comparatively uninjured.

The varieties of currants tested on the station grounds follow in alphabetical order:

Albert Prince.

This variety is but slightly represented in the Station plat. It is considerably lacking in vigor and has been kept closely pruned for propagation purposes. The berries are of good size, white, and sweet.

Cherry.

Both old and young plants were included in the 1896 plat, to which were added young plants in 1898. This red variety produced the largest berries of any variety on the grounds in 1896, and a good yield withal. Some of the berries measured 9-16 inches in diameter. The stems or branches are a little stronger than Fay, but not nearly so strong as Red Dutch or Victoria.

Dubett Tree—*Ribes aurium.*

One plant of this variety was set in the plat in 1897. It has made a vigorous growth, quite upright in character. Although the wood appears to ripen well, yet the leaves near the tips remain quite fresh and green till midwinter or later The variety is being propagated by cuttings and the number of plants will be increased in the near future.

So far the fruit produced has been quite insignificant.

Fay.

Both old and young plants of this variety were set in 1896. The variety is not nearly so strong and vigorous as either Victoria or Red Dutch. It produces a great many new canes of spreading and unkempt habit. The injury from the winter of '99 was considerable. Berries red, medium to large Yield fair to good.

The variety requires extra care to justify the recommendations so frequently given it.

Holland—Long Bunch.

This old sort was not introduced to our plantation till 1897, and then by very few plants, which have since been very closely pruned for propagation purposes. The plants are fairly vigorous, berries of good size, white, and sweet.

North Star.

A few old plants were set in 1896, followed by young plants in 1897 and in 1898. This variety was somewhat injured by the winter of '99. It is strong and stocky, but not nearly so much so as is Raby Castle or Victoria. It is much like Red Dutch in size and bearing propensities but is later in ripening.

Pomona.

But a few plants of this variety were set in the Station plat in 1897 and these have been closely pruned for propagation purposes.

The variety seems to be below the standard for vigor and was very severely killed back by the cold winter. It is a red variety.

Raby Castle.

Old plants of this variety were set in the Station plat in 1896 and young plants in 1898. It is considered by Prof. Card in his handbook on "Bush Fruits" of "The Rural Science Series" to be identical with Victoria. On our ground the two have every appearance of being one and the same variety.

Red Dutch.

Both old and young plants of this variety were set in 1896. It is an old standard sort and one of the best as to bearing propensities, but the fruits are smaller than are the fruits of the more recently introduced varieties. While this variety endures neglect well, yet with good culture and pruning the berries are medium to large in size. It is much like Victoria, but taller and more slender, producing new shoots in abundance. It was apparently uninjured by the recent cold winter.

Versaillaise.

Both old and young plants of this variety were set in 1896. It is nearly as vigorous a grower as Red Dutch, but there are many more shoots which are quite unkempt in habit—much like Fay in this respect, but not so exaggerated. Injury by winter of '99 very slight. Berries are large, spherical, red, rather more acid than our other varieties.

Victoria.

This is the champion variety of the plantation. Set in 1896. Although producing no more fruit than some of the other sorts, it is very strong, vigorous, upright in character and its freedom from the production of many shoots render it a very desirable variety. The fruits are of medium size, red, mildly acid—remaining for a long time on the bushes.

White Grape.

This excellent white variety was reset and new plants added in 1896. The bushes are a little shorter and more stocky than Versaillaise with not quite so many shoots. Stems are somewhat inclined to be prostrate. Apparently uninjured by the cold winters. Berries are large, of a translucent yellowish white color, growing in long bunches, but sweeter than most red sorts—a good bearer.

Probably the best white currant on the market at the present time.

RASPBERRIES—*Rubus*.

Partial reports upon twenty-three varieties of raspberries follow. It is to be regretted that the record of fruiting

is not more complete; but, as stated under the general head "Bush Fruits," this lack of data is principally due to the unusual climatic conditions of 1898 and 1899. Following an extremely wet April, the season of 1900 was unusually hot and dry.

While authorities differ greatly concerning the proper position or location of our various cultivated varieties of raspberries and blackberries within the genus *Rubus*, yet probably the great majority accept the classification given by the American Pomological Society. According to this, raspberries are divided into four species, the European red varieties being *Rubus idæus*, the American reds *R. strigosus*, the black-caps *R. occidentalis*, and the purple canes which are considered to be hybrid between *R. strigosus* and *R. occidentalis* with all degrees of tendency toward either parent, are classified as *R. neglectus*. The purple canes, as a class, are propagated by the tips, and very little, if any, by suckers.

Brandywine—*R. strigosus.*

This old red variety was not introduced to the Station grounds till 1898, consequently there are no adequate notes upon the fruit. The plant is stocky with large reddish colored canes which sucker freely.

Carman—*R. occidentalis.*

This excellent black-cap variety was set in the present plat in 1896. It is an extra early variety. Plants not large, but sufficiently robust. Berries medium size, mild flavor, juicy—in full bearing the latter half of July.

First ripe, July 3; last picking, August 2; full pickings, July 12-19.

Columbian—*R. neglectus.*

This is considered to be one of the leading varieties of the purple canes, being very much like the Shaffer in appearance—a very strong and vigorous grower. It is said to be a very prolific bearer, the fruit being a little later and larger than Shaffer.

Cuthbert—*R. strigosus.*

This old standby of the American red type has not yet been excelled on our grounds, although growing alongside the Marlboro. The plants in a part of one row of Cuthbert were carefully removed and Marlboro set instead, but the latter have been nearly exterminated by Cuthbert plants coming from old underground canes. Cuthbert leaves are narrower than are those of Turner, the latter being especially broad and showing much more color upon the upper surface while young than do Cuthbert leaves. Cuthbert canes have a considerable number of small prickles. Berries are large, dark crimson, broad, conic, grains small and compact. The flesh is good quality, firm, standing up well when picked in quart boxes. First picking, July 10; last, August 23; full picking, July 19 to August 5.

Golden Queen—*R. strigosus.*

This is considered to be simply a sport of Cuthbert, differing from it principally in the yellow color of its fruit.

Gregg—*R. occidentalis.*

This has long been the standard black-cap. Although perhaps a little

slower in attaining to full development than some other varieties, the plants are very large and vigorous, giving an excellent yield. The leaflets are especially broad. Berries are large, roundish, oblate with a decided gray bloom; firm, juicy and of very good flavor. The variety is late in ripening, giving the first picking at the Station about July 21.

Hansell - *R. strigosus.*

This, at one time popular American red variety, was not introduced to the Station grounds till 1898, consequently there is scant data as to its fruiting qualities.

Hilborn—*R. occidentalis.*

This black-cap is quite popular in Ohio and Ontario, but with us it has not done well as yet, although the fruit is near medium size and quite sweet and juicy. First ripe, July 21; last, August 2.

Kansas--*R. occidentalis.*

This variety seems to be the closest rival to the Gregg upon our grounds, although in time of ripening it more nearly coincides with the Carman. The plants are of rapid, vigorous growth, berries similar to Gregg, fully as large, ripening a week earlier; juicy, excellent flavor, quite firm; yield good.

First picking, July 10; last, August 2; heaviest, July 19.

Loudon—*R. strigosus.*

This popular Wisconsin berry was originated at Janesville, being a cross between Turner and Cuthbert. It has not yet fruited on our grounds.

Marlboro -*R. strigosus.*

It is probable that this extremely popular red variety contains an admixture of European or Idæus "blood." By some authorities it is classified as a hybrid between the two species.

This variety has done rather better in neighboring grounds than on the station plat. It is a vigorous and productive early market variety and a thoroughly good all-purpose berry.

Mills—*R. occidentalis.*

This black-cap variety was set in the Station plat in 1898 and has not yet been fruited. The variety is thought to be a cross between Gregg and Tyler.

Miller—*R. strigosus.*

Set in Station plat in 1898; not yet fruited The variety is of the Brandywine type, but said to be considerably earlier.

Mohler—*R. occidentalis.*

This promising black-cap variety was set in the Station plat in 1898 and has not yet fruited. It is claimed to be a seedling of the Eureka, although considered by Prof. Green, of the Ohio Experiment Station, to be practically, if not actually, identical with that variety. It is certainly deserving of trial.

Ohio—*R. occidentalis.*

Introduced to Station grounds in 1898; not yet fruited. An established early variety in many sections. Much used for drying and for shipping fresh.

Palmer—*R. occidentalis.*

Introduced to Station grounds in 1898; not yet fruited. This variety originated in Ohio and has been reported favorably from many sections in the West, and seems to be well worthy of trial here.

Pennock—*R. occidentalis.*

A black-cap of medium slender habit originated by Mr. Chas. E. Pennock, of Bellvue, Colo. The plant is a good, healthy grower, but has not yet fruited on our grounds.

Royal Church—*R. strigosus.*

While classified as an American red, it is quite possible that this variety is a hybrid and should be placed with the *Rubus neglectus* group.

It is a very large and vigorous variety with purple canes, although producing suckers quite freely. Berries are very large, dark crimson, excellent quality, medium firm, stand up well in quart boxes, but are inclined to crumble. It produced the heaviest yield of any variety on our ground in 1897.

First picking, July 21; heaviest, July 31; last, August 23.

Shaffer—*R. neglectus.*

This is an extremely vigorous variety of the purple cane group, of which it is the type. While propagating by root tips, the bushes and also the berries resemble the red raspberries more than they do the black, although the berries grow in clusters much like the black-caps. The berry is large, dark red or purple, moderately firm, nearly as good quality as the reds and richer. It is an excellent variety, but is used more for drying and for canning than for using in a fresh state.

This variety is difficult to lay down unless it is trained to the operation from the first year.

Strawberry-Raspberry, or Rose-Leafed Raspberry—*R. rosæfolius.*

This variety is merely a horticultural novelty in this country. The species is found growing wild in Japan and Eastern Asia. It is of no value except as an ornamental plant and has not endured on our grounds even with winter protection. The summer heat seemed too intense for it.

Thompson—*R. strigosus.*

One of the American reds. Introduced to Station grounds in 1898. Not yet fruited.

Turner—*R. strigosus.*

This is a very vigorous, almost thornless variety, which was very popular for many years. The principal objection is that the berries are rather soft. Berries large, dark red, medium to large, of good quality and yield. The yield is very steady for the first three weeks, the picking season with us being July 10 to August 11.

An excellent variety for home use.

Japanese Wineberry *R. phœnicolasius.*

Set in the Station plat in 1898; failed to fruit; died 1899. It is doing fairly well on some grounds in this section, but is of no commercial value. It is a vigorous, semi-trailing bush of handsome appearance, but so far as fruit is concerned will be of interest only to those who are interested in horticultural novelties. The species is found growing wild in Central and Northern Japan and has long been grown in this country as an ornamental. It was not boomed as a fruit plant till 1889-90.

BLACKBERRIES AND DEWBERRIES—*Rubus.*

But four types of blackberries enter into consideration in this section, viz: 1, the Long Cluster; 2, the Short Cluster; 3, the Loose Cluster, which are thought to be hybrids between the first two and the common Dewberries of the Eastern states; 4, Northern Dewberries. The tendency

among the best growers of this section at the present time seems to be toward the 3rd class, which are more slender and flexible than the high bush varieties, but which, nevertheless, with proper pruning, hold their fruit well off the ground. All of this class that have been grown on our grounds seem to propagate quite freely by suckers and not by root-tips as is characteristic of Dewberries.

The common high bush berries are classified botanically as *Rubus villosus*, and Dewberries as *Rubus canadensis*. Most of the slender-caned loose-cluster varieties being evidently hybrids, are classified as *Rubus villosus* x *canadensis*?

Our old plantation was located on a hot and dry southwest slope, a very improper location, especially in connection with the fact that our supply of water usually fails about the time it is needed for the maturity of the fruit. As a result of these conditions the old plantation has been practically uprooted and a new one in a different location established. Many varieties new to the grounds, as well as all of the old ones, were set in this new plat, the rows of blackberries alternating with rows of black raspberries.

Agawam—***R. villosus.***

This variety is a representative of the short clustered group. It was introduced to the Station grounds in 1896, but has not yet borne fruit of consequence. We had an excellent stand of good thrifty plants. The variety is very popular in many sections; early in season and fruit of excellent quality.

Ancient Briton—***R. villosus.***

This variety is of the long cluster type. It was imported from England into Wisconsin somewhat over forty years ago, where it received its name and afterwards became very popular. It was introduced to our grounds in 1896, where it has obtained a good foothold, but has not yet fruited to any extent.

Dallas—***R. villosus* x *canadensis*** (?).

This blackberry closely resembles the dewberries and is probably either the native Texan dewberry or a hybrid closely resembling the dewberries. The vines are much more upright than are those of the Lucretia or the Mayes Dewberry. The variety has made a good growth on our grounds, but has not yet fruited to any extent.

Eldorado—***R. villosus.***

This variety of the long cluster type originated in Ohio some time prior to 1882. The plants have made a good growth on our grounds, but have not yet fruited.

Erie—***R. villosus.***

This is a variety of the short cluster type originating in Ohio in 1876. The plants are thrifty, lighter green in color than our other varieties, producing a fair yield of fruit. Ripens mid-season, fruit large, short-oval, good quality.

Mayes—***R. canadensis.***

Although originating in Texas, this dewberry is of the Northern type. It has also been sent out under the name of Austin's Improved and reached

our grounds under that name, but these plants failed to become established. The variety propagates by tips and by root cuttings. With us the plants are quite strong and vigorous and appear promising. They have not yet fruited, probably because of inclement seasons

Ohmer—*R. villosus.*

A variety of the long cluster type originated by Mr. Nick Ohmer of Ohio Our plants are vigorous and produced a good yield in 1897. It is mid-season to late; berries large and of good quality.

Rathburn—*R. villosus* x *canadensis.*

This belongs to the loose cluster group and is supposed to be a hybrid, though it is quite upright in habit and is propagated by suckers. The plants introduced to our grounds in 1898 have not done well and have not yet fruited. Mr. Pennock, a local nurseryman and fruitgrower considers this variety by far the best of any of the many he has tested on his grounds.

Snyder—*R. villosus.*

This old and best known variety is of the short cluster type. It makes a large vigorous growth with us but has not yet fruited.

Stone Hardy—*R. villosus.*

This is a variety of the short cluster type originating in Illinois. The most enchanting sight that the writer ever saw in the blackberry line was this variety growing at Madison, Wisconsin, so marvelously loaded with fruit that the large and luscious berries could be literally gathered by the handful. How it may succeed here with sufficient water for irrigation is yet uncertain, although the plants have done well.

Wilson Early—*R. villosus* x *canadensis.*

This variety of the loose cluster type and of hybrid origin was discovered in New Jersey in 1854. It is propagated both by root-tips and by suckers. It is a popular variety in New Jersey, demanding close pruning to prevent over-bearing. With us the plants have done well, giving us the best yield of any variety in 1897 and being about the only one to bear perfect fruit the past season.

Wilson Jr.—*R. villosus* x *canadensis.*

This variety, originated by Wm. Parry in 1875, is said for all practical purposes to be identical with its parent, Wilson Early. On our grounds they appear to be quite similar, but the "Jr." does not equal the "Early" in endurance of heat and drought.

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The Agricultural Experiment Station

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Agricultural College of Colorado.

BROMUS INERMIS.

—BY—

F. L. WATROUS, H. H. GRIFFIN and J. E. PAYNE.

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FORT COLLINS, COLORADO.

Bromus Inermis.

F. L. WATROUS.

Referring to this grass, Press Bulletin No. 47, Kansas Agricultural Experiment Station, makes the following statements: "Awnless brome grass or Hungarian brome grass (*Bromus inermis*) is a native of the dry, sandy regions of Europe and Western Asia. It is a perennial, about the size and somewhat the general appearance of Meadow fescue or English blue grass. It spreads by creeping underground stems or rootstocks. It has been tested by many of the experiment stations, from Canada and North Carolina to Mississippi and California. All recommended it highly for dry, sterile, light or sandy soil."

So far as known *Bromus inermis* was first grown in Colorado at the Arkansas Valley Substation in the year 1892. Out of many different varieties, it alone gave sufficient promise to encourage a second trial. In 1894 the home Station at Fort Collins began investigations as to its value, since which time several sowings have been made in a variety of soils and under widely dissimilar conditions. The grass has been grown on heavy clay with scant irrigation, on the same soil with an ample supply of water, on light soil, above irrigation and on heavy soil, approaching "gumbo," with and without artificial watering. Under all these conditions the grass has succeeded to the extent that a thick, heavy sod has been formed, producing an abundance of forage of rather coarse quality, but readily eaten by horses, sheep and cattle. It has never produced hay in sufficient amount to be considered valuable for that purpose, but sown with alfalfa it promises to be of value for horses. In quality it is believed to be equal to orchard grass, or possibly as good as timothy. It is, of course, inferior to Colorado blue stem or buffalo grass, but where successful it will make up in quantity what it lacks in quality in comparison with these two grasses.

Brome grass produces a very heavy sod, which it is extremely difficult to plow when well set. The ground, to a depth of six or eight inches, will be completely filled with a mass of matted, fine roots, so that the sod will be turned over in solid slices, and remaining of so tough a texture that an excessive amount of

preparatory cultivation is required in order to get in suitable condition to receive any other crop. The disk harrow is the only implement known which will finally subdue this sod. As to the effect on soil fertility, nothing definite is known, although a fair crop of flax was grown upon a plot of this sod ground the past season.

In Colorado *Bromus inermis* is specifically a pasture grass, and it may be truly said it is the only tame grass yet discovered which can, with any degree of success, take the place of the departing pasture grasses of the plains. The closest pasturing and severe tramping have had no effect in destroying the sod. After having been gnawed tight to the ground by sheep, it shows growth within a week after stock is removed, even in late fall when nights are frosty. In the spring brome grass affords pasture from two to three weeks earlier than any other grass known to this locality.

Many complaints are heard from various localities respecting the worthlessness of seed, all of which, thus far, has been imported from Europe. The Kansas Experiment Station reports that about ninety per cent. of this seed fails to grow. Experience at this Station last season seemed to verify this statement, though it is too early as yet to speak with precision in the matter, from the fact that brome grass comes up very much thicker the spring after sowing than would have been expected from its appearance in the fall. Whether this is due to some of the seed lying dormant, or to an extension of the root system at some time between fall and spring, has not been ascertained. The fact has been noted elsewhere, and thoroughly proven here, that it is best not to be discouraged over a seeming light stand the first season, but wait until the grass has a chance to show up the following spring before plowing it up or adopting any radical measures.

For spring sowing, brome grass should be sown early in this country if it is to be grown without irrigation. With irrigation it may be handled successfully by sowing at any time during the growing season. It requires a clean, well pulverized seed bed, such as wheat would thrive in, and should be covered from one to two inches in depth. Owing to the light, chaffy nature of the seed, we have been unable as yet to sow it evenly in an ordinary drill, though this would be the ideal way. It has been sown broadcast by hand and harrowed in. The condition of the soil is of more importance than the manner of sowing.

It would not be safe to recommend this grass for indiscriminate sowing. Farmers having portions of land above irrigation, or desiring permanent pasture on almost any kind of land that is not positively wet or boggy, would be justified in trying an acre or two. Sow fifteen to twenty pounds per acre. If successful, it produces a

good quantity of seed the second year, after which the sowing may be extended with small expense.

The grass has done well and is very useful here. There seems no reason why it should not do well elsewhere.

TESTS ON THE GROUNDS OF THE AGRICULTURAL COLLEGE.

On May 17th, 1894, two plats of land comprising one and a fourth acres were sown at the rate of 16 pounds to the acre. This soil was a sandy, clay loam of such a composition as to have been, in its natural state, practically sterile. Owing to its location being such as to render it very difficult to irrigate, it had been allowed to remain untilled. The land was broken up and gotten in as good condition as possible by aid of disk harrow and roller and the seed covered in fairly good shape. It was irrigated once the first season and made a very poor stand, thickening a little the following spring, and finally at the end of four seasons, made a complete stand, since then producing an abundance of foliage or pasture, but was never allowed to head until the past season, when it produced fifteen bushels of seed.

Another acre was sown on May 25th, 1896, on heavy clay soil and was treated as to irrigation in exactly the same manner as contiguous plats of alfalfa. This plat made an excellent stand from the first and made and produced a crop of seed the second season.

April 9th, 1897, a pasture mixture, composed of barley, rye, oats, sandwicke and brome grass was sown on a small plat of ground for sheep pasture. When sheep were removed, bromus was the only crop to recover. Adjoining this plat, the following spring *Bromus inermis* was sown on about one acre of ground. It was endeavored to sow the seed with an ordinary grain drill. Various substances, as bran and dry soil, were mixed with the brome grass seed to give it sufficient weight to feed through the drill. It was found to be impracticable and the drill was discarded. After sowing, furrows were made about this plat so that one-fourth of the plat would not be watered when the rest was irrigated. The stand on this part was never quite so good as on the balance of the plat, though it was so good that a casual observer would not notice the difference. This lot has been pastured for three years with sheep. As there was always more sheep than the pasture would support, the grass was eaten close to the ground several times each year, i. e., when it was eaten so close that there seemed to be nothing left, the sheep were removed and when water was to be had it was turned on this pasture plat. In every instance the grass came up quickly and when a few inches high sheep were turned on again.

This same season another acre plat was sown for pasture. This soil was very heavy clay, probably as near an approach to regular "gumbo" as could be readily found in this vicinity. An excessive amount of work was necessary in order to get this land in shape for seeding. This however was accomplished and an excellent stand was the result. It was irrigated the first two seasons.

The first season after sowing, the grass having a good start in May, six ewes and their half grown lambs were turned on for pasture. It supported this number for about six weeks, when the grass being eaten down very close, the sheep were kept off and fed for a couple of weeks, in which time the grass recuperated and the sheep were turned on again. This plan was repeated twice more during the season, and in October the ground seemed as bare and nearly as hard as an ordinary road bed. The following spring, however, the brome grass made its appearance in March and with the same treatment each year is still thriving and furnishing as much pasture, to all appearance, as at first.

May first, 1899, two acres adjoining the above plat were sown. The ground had been covered during the winter with a very thick coat of coarse manure, so thick was it in fact that owing to the gumbo quality of the land and its persistent sticking to the plow, only about half the manure was covered up, the rest sticking out and producing a very unfavorable condition of seed bed. The seed was sown however, and covered as well as might be. This land became very dry and it was not thought possible that any of the seed could germinate. After all the other crops on the farm had been irrigated there came an opportunity to run the water on this piece, which was done. At the end of that season a few spears of brome grass were visible, but they were so few that it was thought the plat was

an entire failure. Upon examination early in the following April however, so much improvement was noted that it was thought best to let the land alone, at least for one season, and note the result. By June first there was almost a complete stand of grass, so that sheep were pastured there the balance of the season till October, when the sheep being removed, the grass started up again during the warm days and frosty nights of October and November, showing a thicker stand than could be seen in the middle of summer.

Late in May of 1900, about 14 acres of raw, unproductive land was sown to brome grass at the rate of about 15 pounds to the acre. Considering the quality of the land, the lateness of the season, and the pressure of other work, this undertaking was very ill advised, and would seem to have promised nothing but failure from the first. However about half a stand was secured over a good portion of the land, and the coming spring will show what may be expected of this grass under the very worst conditions.

In the spring of 1898 an experiment was tried on a neighboring farm, of sowing bromus on a high knoll, above reach of irrigation. This soil was a good quality of sandy loam, and having never been irrigated is better calculated to receive and hold falling moisture than would soil which had been irrigated. A fairly good stand was secured here and it has gradually thickened since, producing good pasture, and bas been particularly noticed each spring as producing green pasturage at least two weeks before alfalfa or any other grass.

April 9th, 1898, in a small field thickly sown with alfalfa, a strip 8 feet wide the length of the field was sown with *Bromus inermis* seed. Under ordinary treatment for alfalfa, this strip grew well, was cut three times each year and is still engaged in a struggle for supremecy with the king of the Colorado field. As both were thickly sown, neither crop is at its best, which would indicate that thinner sowing would be advisable where both are sown together.

Trials at the Arkansas Valley Substation.

H. H. GRIFFIN, Superintendent.

April 22, 1892, a plat 145 feet long, 67 feet wide, was sown to seed of *Bromus inermis.* An excellent stand was secured, and the records report it growing ten inches tall and producing seed. In 1894 this plat was harvested July 12th, and from the product 208 pounds of cleaned seed was secured. By this time the sod had become very close, and most of the growth made was around the edges of the plat. Wherever it was sub-irrigated the growth was from one to two feet high, but wherever flooded it became sod bound and made almost no growth.

This was about the manner of its growth the succeeding years, until the present Superintendent took charge, in March, 1898. Noting that it was making a very poor showing, a portion was given a dressing of gypsum, and a sharp implement in the nature of a sub-soil plow was run through the other portion to cut up the sod, thinking it might do better were it relieved of the sodded condition. Neither remedy proved to be of any benefit. The only growth of any importance was the narrow fringe around the edges, or on the ditch banks, where it secured sub-irrigation. It does not

seem to withstand flooding. Becoming satisfied that no returns were to be secured by further allowing this to stand, it was plowed up in the fall of 1898. The sod was extremely compact, and much of the season of 1899 passed before it was rotted.

To a field of three acres that had been sown to rye in October, 1894, was added *Bromus* seed on April 9th, 1895, at the rate of twenty-six pounds per acre. The seed was harrowed in, and germination secured by irrigation. A fairly good stand was secured over the greater portion of the field. In 1896-97 it furnished some pasture during a portion of each year. In 1898, when first taking charge of the Station, it was noted that this grass started to grow very early in the spring. It made some growth until about the middle of May, when all development stopped. It remained in about this condition until fall rains occurred, when it made some further growth, but not enough to warrant giving it much consideration. It was also noted that where an application of barnyard manure was given, that the growth was increased considerably. It was further noted that while the grass would withstand considerable drouth without dying out, yet to secure any growth or vigor of plant a considerable amount of moisture was necessary, and this moisture should preferably be in the form of rain. Nine irrigations were given this field in 1897, between March 26th and October 1st. As before stated, where flooded it soon became sod bound. As the returns from this field did not warrant retaining it any longer, it was plowed up in May, 1899, and seeded to corn.

That this grass did not improve the fertility of the soil was apparent from comparisons of adjoining fields, both in 1899 with corn and in 1900 with oats. An adjoining field that had been in red clover, and plowed up at the same time of the *Bromus*, gave fully fifty per cent. greater yield in the two crops above mentioned.

Not being satisfied that the trials had been conclusive with this grass, and thinking that perhaps fall sowing would be of benefit in securing more favorable results, a field of one and one half acres was prepared, which was seeded with seventy pounds of *Bromus* seed, September 7, 1898. This land was irrigated by means of furrows two and one half feet apart through the land, in which the water was run, giving it sub-irrigation as much as possible. A splendid stand was secured, and the grass was up well before winter set in. It was given the best of attention in 1899, and the heavy rains of the summer and fall were conducive to its best development. The results of the year were promising, and it appeared as though this grass, under such conditions, would prove a valuable adjunct to the agriculture of this section. It was pastured but slightly in the fall of 1899, and by the 20th of April, 1900, furnished quite good pasture. One dairy cow was turned upon this lot and pastured for about six weeks. While there seemed to be a

plenty of forage, the cow did poorly. She lost in milk and flesh, so much so that it was necessary to seek some further food to secure good results. Early in May this grass began to fail, and from that time to date of this writing (December 28th) has only lived, making no growth whatever.

The season has been very hot and dry, and under such conditions, which often prevail, the artificial application of water does not seem to be the requisite to produce growth and vigor of plant. Its behavior here tends to show that it is better adapted to a region of lower mean temperature and greater summer precipitation, and that the soil should contain much more clay—what would be termed a stronger soil. It becomes sod bound under irrigated conditions, and soon fails to produce growth of any value. The grass is coarse and very low in nutritive qualities. I see but one place where it may profitably be employed, and that is as a soil retainer on the banks of ditches that are liable to wash. The fact that it thrives where the water is applied in this way, and that it forms such a dense sod, would warrant its use in cases such as above mentioned.

Trials at the Plains Substation.

J. E. PAYNE, Superintendent.

1895. A plat was sown March 22nd on well prepared ground, which was broken in 1894 and thoroughly plowed in March, 1895. This seeding was blown out by spring winds. Later in 1895—June 6th—the same plat was sown to *Bromus inermis*. A good stand was obtained, but grasshoppers destroyed it all.

1896. Seed from an unknown source was used to sow a plat to *Bromus inermis*. The ground was well prepared, and had been cultivated in 1894 and 1895. None grew. The plat was seeded May 2nd.

1897. A plat was sown May 2nd, on well-prepared ground which had been in sorghum in 1894, 1895 and 1896. No stand was obtained—in fact no grass was seen to have grown from this planting. Seed: The same as that used in 1896. It was of unknown origin, but was bought from a reliable seed house.

1898. A two-acre plat was sown on land which had been well cultivated in sorghum and corn during the four years 1894, 1895, 1896 and 1897. Seed furnished by the Department of Agriculture was used. This seed was imported from Russia. A good stand came up, and the grass promised well until late in the

summer, when the dry weather killed much of it which grew on the higher part of the plat. The grass remained green until late in the fall, and stood the winter well. It started in the :spring of 1899, about the same time that the Colorado bluestem (*Agropyrum sp.*) started, but the dry weather in the summer destroyed nearly all except that which was in a low place, where extra water collected. This patch threw up a few seed-stalks twelve inches high. The spring of 1900, more especially April, was very wet. The remaining grass thickened and completely occupied the ground where it had secured a foothold (this was confined to about ten square rods which got the benefit of storm-water from the prairie). The seed-stalks grew twelve to twenty inches high, but they were thin on the ground. The main, leafy parts of the plants were too low to be cut by the mower.

1899. Seed sent out by the U. S. Department of Agriculture in 1898 was used to sow a plat on ground which had been cultivated in hoed crops since 1894, with the exception of one year, when it was in barley. Only a few plants appeared, and these died during the dry weather of the summer. This plat was sown April 20th.

1900. Fresh seed, grown in Manitoba, was furnished by the U. S. Department of Agriculture for seeding a plat this year. It was sown on well-prepared ground, which had been cultivated in hoed crops every year except one since and beginning with 1894. Only a few plants appeared, and these died during the summer. This plat was sown April 23d.

NOTE 1.—"Well-prepared ground" means that the land was plowed from five to eight inches deep and thoroughly harrowed until the seed-bed was practically free from clods. In 1898 and 1899 the land was plowed eight inches deep and packed with a sub-surface packer.

NOTE 2.—The choice land of the Farm was used every year except 1898, when a two-acre piece, which represented the wettest and the dryest land on the Farm, was chosen.

NOTE 3.—Seed. The seed used in 1895 and 1898 proved to be good by growing. The seed used in 1896 and 1897 may not have been good, as its origin was unknown. The seed used in 1899 was some which was left from the supply sent by the U. S. Department of Agriculture in 1898. The seed used in 1900 was fresh seed obtained from the Department of Agriculture, which was grown in Manitoba. Also some of the old supply sent by the Department of Agriculture in 1898 was sown. Both these gave about the same number of plants.

NOTE 4.—All seed was sown broadcast and harrowed in with a smoothing harrow.

BROMUS INERMIS SEEN ELSEWHERE ON THE PLAINS.

Only one plat was seen growing. That was on the ranch of Robt. Lucore in the northern part of Lincoln county. I saw this plat in May. 1900. It then showed scattered bunches among the weeds. The grass appeared to be growing well, but was a very poor stand. It was a small plat. Mr. Lucore said that he thought *Bromus inermis* a good grass for his neighborhood, but he did not care to plant any more, even if the seed was furnished him free.

WEATHER AND COMPARATIVE CONDITIONS.

During the six years *Bromus inermis* has been tried here, the rainfall has been as heavy as usual. Native hay has been cut on the uplands every year, except 1900. No year of the six under consideration was as drouthy as were 1893 and 1894.

GENERAL COMMENTS.

1. In common with all so-called drouth-resistant plants, the testing of *Bromus inermis* has proved to be very unsatisfactory here. The failure to get a stand of plants is the greatest difficulty experienced. If rain does not fall at the right time after seeding, we are almost sure to fail to get a stand which will be fair to the plant under consideration. If a stand is obtained, continued drouth before the young plants are strong enough to resist it, may destroy all hope of successful termination of the trial.

2. While we feel that the grass (*Bromus inermis*) is a failure under the conditions existing here, we realize that it might succeed where conditions are not quite so unfavorable. A difference in the distribution of the rainfall might bring success where we have to record failure.

Our experience and observation compels us to recommend to those who think of trying *Bromus inermis* on unirrigated land in eastern Colorado, that they test it on a small scale for a few years, before plowing up buffalo grass to make room for it.

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The Agricultural Experiment Station

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CANTALOUPES.

—BY—

H. H. GRIFFIN.

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"Netted Gem" Cantaloupes, grown at Rockyford, Colo.

THE CANTALOUPE.

BY H. H. GRIFFIN.

INTRODUCTION.

The Arkansas Valley of Colorado has for some years been famous for its cantaloupes.

During the season of 1900, 780 cars were shipped, which represents the product from about 2,500 acres.

The cantaloupe is known as the "Rocky Ford" from the town that has led in the industry. The variety grown is the Netted Gem, which Burpee claims to have the distinction of originating. Through environment it has become so perfected in the vicinity of Rocky Ford as to be unsurpassed in quality, and needs only to be introduced in any market to at once take possession of it.

The melon plant is of rank growth and succulent tissue. It thrives best under conditions of high temperature, dry air, and continuous sunshine, and a deep, warm, sandy loam soil. It is as delicate in constitution as in texture. It does not adapt itself readily to varying conditions nor to sudden climatic changes, and its tissue offers little resistance to the attacks of fungi.

CULTIVATION.

Were it not that there are many amateurs growing this crop, owing to the rapid settling of the lands in the Arkansas valley of Colorado, this bulletin need not deal with this phase of the subject.

The first planting is done from the first to the tenth of May; seldom any advantage is gained by putting the seed in earlier than May 1st. The land is put in good condition by rather deep plowing, harrowing and leveling. Furrows are then run with a shovel plow from 6 to 7 feet apart and the seed planted by the side of the furrow, making the hills from 5 to 6 feet apart in the rows. Uniformity of planting facilitates cultivation, as for a considerable time the field may be cultivated in both directions. Care must be exercised not to plant the seed too deep. The depth should not exceed one inch.

Some growers irrigate the furrows and plant afterwards, while others plant and then irrigate, permitting the water to reach the seed by percolation. I prefer subirrigation to

germinate the seed, as the soil is apt to become crusted and dry if it is handled and pressed after irrigation.

Plenty of seed should be used—from 10 to 15 seeds to each hill—and when the plants have put forth four leaves, thin to three plants for each hill. Cultivate and hoe sufficiently to secure good tilth until the vines run well, or are from two to three feet across the hill. Then the irrigating furrows should be run and cultivation cease, giving such hoeing as will keep down weeds.

SEED.

Good seed is a prime requisite for success with the cantaloupe, but not enough attention has been paid to the selection of it. Few have made any systematic selection of seed, looking well to the shape, size, solidity, depth of flesh, seed cavity, color of flesh and quality. Many have bought from dealers who knew little of the quality of seed sold, and the result is that many melons sold as "Rocky Ford" are not up to the standard. The effect of poor seed is more apparent in those districts in which there are many amateur growers, than where the older growers predominate.

A pure Rocky Ford cantaloupe when ripe should have a silver colored netting which is lace-like in appearance. The skin should be green turning to a peculiar gray color when the melon is fit for shipping. The flesh should be green in color and so sweet and luscious that it may be eaten close to the rind. The melon should have a small seed cavity and the portion of the flesh immediately surrounding it be slightly tinged with yellow. The melon should weigh about one and one-half pounds and be very solid and firm.

The cantaloupe growers should save seed from the very best melons, for in this way only can the quality be maintained or improved. No grower should save seed for his planting without testing the quality of the melon. Occasionally a melon may be perfect in appearance, but not of first rate quality.

HARVESTING.

Much seed is shipped to points outside the state and the product from this seed is shipped to market as "Rocky Ford" melons. "Rocky Ford" melons, so called, are on the market about the time the melon is setting on the vines in the Arkansas valley. A few melons are shipped the first week in August, but heavy shipments do not commence before the middle of the month. The melons are picked into sacks, carried over the shoulders of the pickers, and are at

once taken to the shade—packing sheds being made for the purpose—where they are crated. The standard crate holds forty-five perfect melons, in three tiers of fifteen melons each, and weighs about sixty-nine pounds. There are also used, to some extent, the two-layer crate, which is two-thirds the size of the standard, and the "pony" crate holding forty-five melons, but smaller than those of standard size. The standard crate is (inside measurement) 22 inches long, 12 inches wide and 13 inches deep.

When it is proper time to pick for shipment, the stem slightly parts from the melon. No stem tissue should adhere to the melon, but there should be a smooth surface where the stem was attached. The netting and skin has a peculiar grayish appearance, which is easily distinguished when one becomes accustomed to picking.

The cantaloupe is very perishable and rapid transportation, in refrigerator cars, is required. By this means melons of good quality are placed in all of the markets of the eastern states. The shipping period (from the same vines) should extend over not less than thirty days; a more rapid ripening than this is generally indicative of unhealthy conditions. As high as 300 crates per acre have been taken from alfalfa sod, but 100 to 150 crates of marketable melons per acre is considered a good yield.

IRRIGATION.

The essential thing in irrigating is to keep the water confined to the furrow, reaching the roots only by percolation. This keeps the soil in good condition, does not cover the vines with mud, and leaves the fruit in dry condition. If the water stands on the fruit it is apt to induce decay or cause uncolored or soft spots, which make the product unsalable. It is common to irrigate every ten days, paying little attention to the needs of the plant. The tendency is to irrigate too often early in the season.

The most water is required about the time the blossoms commence to set well, previous to this giving only enough to keep the plant growing well. When the plant commences to bloom profusely, irrigate thoroughly and afterwards give only so much water as will keep the plant in good thrifty condition. A too moist condition is apt to increase the spread of any fungus trouble.

In 1899 three plats were used to test the effect of irrigation on quality and production. One plat had seven irrigations, June 19, 30, July 10, August 1, 17, 26, and Sep-

tember 4; another three irrigations, June 30, August 1, and September 4; and a third plat one irrigation, July 10. Heavy rains occurred in July, and considerable rain fell in August.

The plat irrigated but once did not yield so heavily as the others; the vines and fruit were smaller, but the fruit was of better quality. The plats numbered one and two yielded about the same, and as far as could be judged, the quality was the same. Evidently, plat No. 1 received twice as much water as was necessary.

FERTILIZERS.

Virgin soils produce good melons both in quality and quantity, but fertilization is soon a necessity. Since fungus troubles have become annoying, it is not advisable to apply any heating manure to the soil just previous to growing cantaloupes, as it has a tendency to increase the trouble.

A comparative trial in 1899 with melons grown on alfalfa sod, on cropped land manured with well rotted barnyard manure in the hill, and on cropped land fertilized with bone dust in the hill, showed the best results from the alfalfa. The product was nearly doubled, the quality was better, and the ability to resist fungus troubles greater. Alfalfa sod brings maximum returns, and in turn the melon easily subdues the alfalfa and puts the land in splendid condition for succeeding crops.

TRANSPLANTING.

A test was made in 1899 to note to what extent hot bed propagation may hasten maturity and how successfully it may be performed. The seed was put in the hot beds April 3. Some of the seed was put in cans, so arranged that the plants could be taken from them without disturbing the roots, while others were put in the bed without any support. It was found quite difficult to transplant them when the roots were at all disturbed. Fully 95 per cent of those set from the cans grew, while only about 50 per cent of those taken from the bed without support survived. May 8, the first plants were taken from the bed and set in the open field. The first seed planting in the open field was April 29 and the second May 10.

The first ripe melon was taken from the transplanted vines August 17, only one day earlier than melons grown on ground fertilized with alfalfa or manure, and only four days earlier than those grown without any fertilizer.

However, they ripened (in quantity) faster, and for the next ten days gave more ripe melons than any other planting.

DISEASE OF THE VINE.

Until recently the industry has advanced at a rapid pace, no disease or insect pest causing trouble of any consequence.

A blight or rust first attracted attention in a few fields in 1896, and there was a slight increase in its spread in 1897. No one gave it serious thought at first, and it was not until it became prevalent and the damage serious, that anyone realized to what extent it might cripple the industry. My attention was first called to it in 1898, when it became so prevalent in some fields as to do much injury to the crop at about the time the melons were ripe.

It first appeared in well defined centers on fields that had been cropped with melons continuously for some years. In 1899 it was apparent that the disease diminished as we receded from these centers, and, in most cases, it did not appear on the remote fields until later in the season.

The leaves were found to be covered with numerous brown spots, giving them a rusty appearance. The spots ran together, eventually killing the leaf. The stem was also covered with spots, and in some cases the melon was affected, the diseased tissue often extending to the heart of the melon.

Leaves and stems were sent to Prof. Crandall, who pronounced the trouble due to a fungus (*macrosporium*), but sent the specimens to Ellis and Everhart, who pronounced it a new species, naming it "*cucumerium*."

To the casual observer, the cantaloupe blight, which is caused by a true parasitic fungus, first appears as a number of brown spots about the size of a pin head upon the leaves in the center of the hill. A careful examination of the younger leaves shows where the fungus has been at work, sometime before it is apparent by the brown appearance. It can be seen where the leaf tissue has been eaten away, and when the injured tissue dies, then it is that the brown appearance occurs. These spots gradually enlarge until they may attain a diameter of half an inch, and the number sufficient to envelop the leaf and cause its death. In some badly affected fields can be seen spots of all gradations in size, from those just forming on the young leaves to those so large as to destroy the older leaf.

During nearly the whole season the cantaloupe is putting forth new growth that is very succulent, and this

parasite may be doing incalculable injury long before the grower is aware of its presence. This is especially true if the weather conditions are moist and favorable to its increase and spread.

EXPERIMENNTS IN 1899 FOR THE CONTROL OF THE DISEASE.

Observing in 1898 that the disease was apparent only on certain fields, I made a collection of seed from these for planting the following year, to see if it was communicated by the seed. This seed was planted in the spring of 1899 away from other melons for the purpose above mentioned, and for some preliminary spray work for the control of the disease.

Three rows, each 250 feet long, were planted, the middle one being reserved for spraying with the Bordeaux mixture, using the others as checks. The row was sprayed June 22, and again June 30, with Bordeaux mixture—4 pounds of copper sulphate (blue stone) to 40 gallons of water. At this time there was something on the vines that looked like blight. The next spraying was done the 22d of July, at which time the blight was in evidence and spreading rapidly. The row was again sprayed July 31 and August 11.

The weather previous to June 19 had been very dry. Subsequent observations have shown that the spread of the disease, previous to this time, would not have been rapid enough to be discerned, even if the weather had been moist.

After June 20, rain and dews were plentiful; seven inches of rain fell during July, 5.14 inches of this in the week commencing July 14. The vines were completely submerged and the spray, no doubt, mostly destroyed. The weather conditions following were very favorable to the spread of the disease.

Owing to the weather conditions during July, it was not apparent that any benefit was secured from the two early sprayings, but a decided benefit was obtained from those made after July 22.

The sprayed vines remained green and in a growing condition long after the others had succumbed to the disease, and fruit of good quality was picked from them the first week in September. Two weeks previous to this the last merchantable melons were taken from the unsprayed vines and they, at all times, were inferior in quality to those picked from the sprayed vines. They ripened prematurely and the taste was insipid; this alone being sufficient

guide to determine from which vines the melons came. It could not be said that the infection came from the seed, for these vines were no worse infected with the blight than other melons on the station property or in the adjacent country. Some of the seed was held over for planting in 1900, and the results are like those mentioned.

All of the fields in the vicinity of Rocky Ford were more or less affected with the disease, the spread being much more rapid than anyone anticipated. This caused us to inaugurate experimental work, late in the season, for its control.

There were, at the station, seven rows of cantaloupes, each 275 feet long, on alfalfa sod. One of these was sprayed with the Bordeaux mixture July 31, and again August 11. This work confirmed the results enumerated above.

Another row was sprayed with the ammoniacal copper carbonate solution (1 oz. to 6 gallons of water) August 4, and again August 8 and 11. Some benefit was secured from this spray, in the same way it was with the Bordeaux mixture, but it was not so pronounced, nor does the spray adhere so well to the plant.

Mr. I. D. Hale had some June planted melons which we secured for experimental purposes. They were sprayed with the Bordeaux mixture July 27, and again July 31 and August 11.

About one-eighth of an acre of melons was sprayed for G. W. Swink, August 15 and 16. Owing to press of work only one application was given these vines, but the benefit from the spray was quite marked when compared with the remainder of of the field.

August 21 we sprayed about one acre of late melons at I. D. Hale's, in which the blight was very bad; it appeared as though no returns could be secured from the field. Even after the vines were thus affected there was a marked improvement in the appearance of the vines, and the fruit did not deteriorate in quality nearly so rapidly as in an unsprayed portion of the field.

Mr. C. S. Fenlason had about 1¾ acres of late melons which were secured to spray, to verify previous results and to further study the cost of the work. The vines were very large, completely covering the ground.

A barrel of spray mixture was put in a slip scraper which was pulled backwards, and two rows taken on each side. The work was done August 22 and 23. Twenty-two pounds of copper sulphate were used to make

the spray. It required three men and one horse thirteen hours (together with a boy about two hours to turn the vines) to complete the work. The cost was estimated at $6.75 per acre.

Three hundred crates of good melons were sold from the field. Mr. Fenlason thinks the spray saved the crop from destruction. A few vines in this field were not sprayed and the advance of the disease on these was very noticeable. An adjoining field of melons so succumbed to the disease as to be of little value. The results of the year were of one accord; confirming the benefits from the spray as above mentioned.

EXPERIMENTS OF 1900.

The cantaloupe season was very dry and hot, and hence extremely favorable to the vine and unfavorable to the spread of the disease, so that the results have not been so marked as was the case in 1899, when rain was prevalent.

May 8 about six-sevenths of an acre of alfalfa sod was planted to cantaloupes, it being the intention to spray portions of it at stated intervals for the purpose of testing what number of sprayings would be the most efficient. June 11 the blight seemed to be making its appearance and the vines as yet not running. The same appearance was also found in other fields. June 13 the most of this patch was sprayed with Bordeaux mixture, July 11 sprayed the second time, and July 31 a portion of them sprayed for the third time.

The weather continued extremely dry and hot during July and August, and in but few places was there any rapid spread of the disease. There was no appreciable benefit from the third spraying.

Comparing the sprayed vines with checks and with adjoining unsprayed fields, there was an appreciable difference in the appearance of the vines, in the quality of the fruit, and the manner in which it ripened. During the last of August, the fruit on the sprayed vines was ripening slowly, while the unsprayed vines were giving up their fruit rapidly.

About four acres of melons, belonging to leasers on the station, were used for experimental purposes. Two acres of this field were sprayed June 14 while the vines were quite small, but few of them running. A second spraying was given them from July 7 to 12, at which time they were running considerable.

A third acre was sprayed July 28 for the first time, which was done for the purpose of noting the effect of late spraying. The blight was showing considerably in the center of the hills, but not spreading to any appreciable extent. After this spraying there was a peculiar appearance of the edges of the leaf (which to some might be alarming). Much of the portion assuming this appearance was brown at the time of spraying, but the centers remained green and the leaves retained their vitality, which was not the case with those unsprayed. This appearance of the edge of the leaf did not occur with those sprayed early, and its appearance is something for which I am not able to account. The remaining acre was not sprayed, for the purpose of a check upon the work.

The most noticeable feature to the parties picking the product from the field was the rapidity with which the unsprayed portion ripened its fruit. Soon after harvesting commenced the yield on this acre was twice as great as on an equal area of sprayed vines, and the quality was not so good. The melons were ripe and picked on this acre fully two weeks before they were on the other three acres. Those having the field in charge were in doubt, when the work commenced, whether there was any efficacy in the spray, but the ripening of the fruit dispelled any such doubt. There was an appreciable difference in the appearance of the vines, and this was discernable for some distance. People who saw the vines early in September would remark as to their health and vigor, and they continued to bear until frost.

Owing to the continued dry weather, the two early sprayings seemed to be all that was required, and were preferable to the one spraying done later. Had moist conditions arisen, it is probable that one or two more sprayings would have been necessary. However, the results from the late work gave evidence that good results can be secured from the late applications.

What has been said is further substantiated by results in other fields near by, in which the vines and crop were, at one time, more promising, but (due to the diseased conditions) ripened their fruit too rapidly, unevenly, and the quality was undesirable. On these fields the spread of the disease from day to day was apparent during the latter part of August and the first week of September.

An ordinary field of cantaloupes should not yield, during the height of the season, more than twelve crates of

marketable melons per acre per day, but on some diseased fields it was not uncommon for more than twice that amount to be taken.

As a further test of the efficacy of the Bordeaux spray, four acres were sprayed in the field belonging to John Deweese. The first application was made June 18, and the second July 7, it being the intention to give a third, but press of work prevented it. One row was left through the center as a check, and the results showed a decided benefit to the vines and the ripening of the fruit. This was especially marked when comparison was made with an adjoining field that was planted later, but which matured its fruit earlier, owing to the disease.

Mr. Deweese feels that the spraying saved a considerable part of his crop. His greatest yield from the four acres did not exceed 50 crates per day, in a total yield of about 600 crates. When the season was nearly closed and the vines had been tramped and injured, the benefit, from the appearance of the leaves, was still apparent.

I had under observation four fields, in which spraying had been done by farmers who were incited to do the work by the results of the previous year. Some were highly pleased with the results, and in no case was there a failure to derive some benefit.

I wish to emphasize what has been said in regard to the benefit on the quality of the fruit—the value of the spray is not by any means to the vines alone. It keeps the vine in better health, and the necessary vitality is secured for the proper development of the fruit.

COST OF SPRAYING.

A record of expense on the field of John Deweese for labor and material is as follows: June 18, 4 hours with 3 men, 1 team and 1½ barrels of spray mixture. July 7, 9 hours with 3 men, 1 team and 3½ barrels of spray mixture. An estimated total of $9.80 for two sprayings on the four acres.

The cost of spraying the two acres on the station, twice, is as follows: June 14, 1½ hours with 3 men, 1 team and 1 barrel of spray mixture. July 7 to 12, 2¾ hours with 3 men, 1 team and 1⅓ barrels of spray. The acre sprayed July 28 required 3 hours with 3 men, 1 team and 1½ barrels of spray, together with 1 hour for 1 man to turn the vines. This makes an average cost of $4.47 for spraying an acre three times. The vines varied in size from those just running to vines from 3 to 4 feet across.

These estimates, together with those for 1899 at Mr. Fenlason's, cover the cost at all stages of the melon's growth, and from this one can tell approximately what the cost will be, taking into consideration the size of the vines. The price of copper sulphate (blue stone) is assumed to be ten cents per pound in these estimates.

Our appliance for doing the work in 1900 was a platform arranged on two wheels of a grain drill, upon which was a barrel containing a spray pump. Two lengths of hose were attached to the pump, sufficient to cover from 4 to 6 rows at a time, depending upon their size. The double-trees were spread to correspond with the width of the wheels and allowed the team and cart to spread over one row.

ACTION OF THE FUNGICIDE.

The object in applying the fungicide is to destroy the fungus without injuring the plant tissue. Further infection will be prevented and the tissue that the parasite would otherwise appropriate will be left to perform the functions of the plant.

The Bordeaux mixture is a combination of copper sulphate (blue stone), lime and water. The lime unites with the sulphuric acid, forming gypsum, and the copper is left in an insoluble condition which the gypsum tends to cement to the leaf. The carbonic acid of the air and the ammonia of the rain and dew dissolve slight amounts of the copper. It is very essential, when preparing this mixture, to use plenty of lime—an excess will do no harm. Experiments have shown that when an excess is used the copper is slower dissolved and, consequently, held on the plant longer. There are a number of ways the copper may act upon the fungus.

The spores may be prevented from germinating by inhibitory action; the spores may be killed outright before germination has commenced; the germ may be so weakened as to be unable to enter the host plant; or the presence of the copper on the leaf may impede the fruiting of the fungus already within the tissue of the plant. I believe the efficacy of the spray is due to the destruction of a considerable portion of the fungus growth present and to the prevention of the germination of the spores upon the new tissue. That the spray quickly prevents the enlargement of the spots is plainly to be seen.

The spores of the fungus, no doubt, germinate, grow and produce spores in a few days, but this period of growth may be hastened or greatly retarded by the weather con-

ditions that prevail, and for this reason the results may vary, according as one is fortunate in applying the spray at just the time when it may be most destructive to the fungus. The development of spores apparently takes place faster in late than in early season, which, no doubt, accounts for the greater rapidity of its spread later in the season.

EFFECT OF WEATHER CONDITIONS.

The season of 1899, being alternately wet and dry, afforded an opportunity to study the effect of weather upon the development of the fungus. When moist conditions prevailed, its spread was so rapid that it was plainly apparent, but dry weather at once checked it.

The number of sprayings required, and the time at which the spraying should be done, will have to be regulated largely by the weather conditions. When it is remembered that there may be, under favorable conditions, many successive crops (so to speak) of the fungus, and that moist, humid conditions are the most favorable for its growth, the grower will have to be guided by the weather in choosing the time for making the application.

The grower is mostly interested in preserving the leaves in the center of the hill, and for the purpose of doing this we think it well to give one or two sprayings about the time the vines commence running. The leaves in the center of the hill give protection to the major portion of the marketable melons.

The season of 1900 was extremely dry and may be considered as unfavorable for the blight as any season could be, and yet the disease was prevalent. While it did not develop to such a degree as to greatly impair the quality of the fruit in the majority of fields, yet in most instances there was more or less injury. In some fields the shipping season was shortened fully one-half, and the product was of inferior quality.

It is far preferable that weather conditions should keep the disease under control every year, but as the disease was prevalent in 1900, the farmer must expect to be obliged to cope with it under the weather conditions that usually prevail.

The farmer must not think, from what has been said in the preceding pages, that perfect immunity is secured by the use of the spray. All that can be hoped for is such control of the disease that melons of good quality may be secured, and the shipping season prolonged to near the

same period that it would be if perfectly healthy conditions prevailed.

The subject is not exhausted in this report, but we have done enough work to warrant giving information to the farmer, that he may be able to cope with the trouble to the fullest extent that our knowledge, at present, will enable him to do.

PREVALENCE OF THE BLIGHT.

No evidence could be secured in 1899 that the disease occurred in any other locality than that of Rocky Ford. In 1900 I found it in all parts of the valley, with the possible exception of Pueblo. Many farmers are yet totally ignorant of its appearance, especially when it is not present in sufficient quantity to cause any rapid deterioration of the crop. A farmer, whose field was badly infested with lice and blight, cited the fact that he had shipped 200 crates per acre from the field. Inquiry revealed the fact that the shipping period had not extended over more than two weeks, and that many melons of inferior quality had been taken because, just at that time, the supply of melons was not equal to the demands of the market.

INJURY TO BEES.

Many hives of bees stood near one of the fields treated. The apiarist found no dead bees, nor could it be seen that any harm resulted to the bees. The blossoms of the melons live only three or four days, so that no great number of sprayed blossoms are on the plant at any one time. Most of the flowers are well protected by the leaves, so that but little of the spray reaches the center of the flower.

FORMULA FOR MAKING THE SPRAY.

Dissolve 4 lbs. of copper sulphate (blue stone).

Slake 4 lbs. of fresh lime.

When the lime has become cool drain off the milk, adding it to the copper sulphate solution; then dilute with water until there are 40 gallons of the mixture. These proportions we have found to be about right, but care must be exercised to use plenty of lime, or otherwise the acid will burn the foliage. It is better to err on the part of too much lime than not enough. A stronger solution can be used with impunity, but we have found as good results from this as from the stronger.

POLLINATION.

The number of flowers born by a single melon vine is something astonishing. This is no less striking than the disparity existing between the male and female flowers. An account was kept on six vines from June 27, the time of blooming, until July 13, at which time the vines had become so interlapped that individual vines could not be distinguished.

The table shows the dates on which the flowers were counted and the number of flowers that had formed at each time. The total number of male flowers formed was 3,075 and the number of female was 253; an average to each hill of 512 male and 42 female flowers to July 13:

Date.	No. of Male Flowers.	No. of Female Flowers.
June 27	203	1
June 30	338	11
July 3	474	28
July 7	755	95
July 10	660	87
July 13	645	31

It must be remembered that the vines continue to bloom profusely until late in August and melons may ripen that are set about the middle of August.

Twenty ripe melons to each vine is considered a heavy yield. In the above table we have more than 40 female flowers (to each hill) produced in the first two weeks of the blossoming period.

The first blossom appeared on June 27, and the first ripe melon was taken August 11. It takes about six weeks from the time of the setting for the fruit to ripen. Some farmers become alarmed when the first flowers that are formed drop without setting fruit, but the figures reveal the fact that the most of these are not fruit bearing flowers.

INSECT PESTS OF THE CANTALOUPE.

Flea beetle—This is a small black beetle that devours the leaf soon after the melons are up. Dusting the plants with air slaked lime in early morning when they are damp, or spraying them with a mixture of 1 lb. of Paris green and 1 lb. of lime to 150 gallons of water, will remedy the trouble.

Striped cucumber beetle—This little striped insect is familiar to all, appearing in the spring soon after the melons

are up. It has not appeared at the station since June, 1898, at which time trials for its control were cut short by a severe hail storm. I have seen good results from dusting the plants with Paris green in air slacked lime, but it is only a repellant, and hence the effect is temporary. It will drive them away for a time, but they may return with the next passing wind. In the short space of time we were enabled to combat it, we found kerosene emulsion quite effective. It acts as a repellant and kills with sufficient contact.

In Bulletin 158 of the Geneva (N. Y.) station, Bor deaux mixture was found to be the most efficient of many remedies tried. From a knowledge of its repellant properties, we are of the opinion that it will do all that is claimed for it. Its use will be a double one—for the insect and the blight. The insect is not present every year, but is very destructive when it does appear.

Geometer or measuring worm—This worm did much harm in 1900 by eating away the parenchyma of the leaf from the under side. It appeared about June 18 and was very near the color of the leaf, and exceedingly small. It was sometimes difficult to discern, and did much injury before many were aware of its presence. These worms are numerous every year on lettuce, cabbage, etc., but last year was the first time I have known them to attack cantaloupes. I noticed when we had sprayed with Bordeaux mixture for the blight, that but few of the worms were present.

We also used a spray of Paris green, 1 lb. and lime, 1 lb. to 150 gallons of water, which was effective. In using Bordeaux mixture for the blight the poison can be added to lessen the numbers of the insect, and thus apply a remedy for both evils at the same time.

Melon louse—This is the only insect that may cause alarm to the melon growers. In the eastern part of the valley it has secured such a hold that drastic measures will probably have to be taken for its suppression. I saw many melon fields in 1900 almost ruined by this insect. The insects were so numerous that the vines over whole fields were black from the excretion of honey-dew. They were so numerous as to cause inconvenience to the pickers, and yet there were many growers not aware that the insect was present in the field. The lice were sapping the vitality of the vines and destroying the quality of the product.

The insect breeds and feeds upon a great variety of plants, many of which are the common weeds of our fields. Winged forms will appear and migrate to the melons. The

lice reproduce so rapidly that once they become established it may be only a short time until the whole field is infested.

Probably the best remedy is a preventive one, which consists in keeping the weeds cleared from surrounding fields, and the burning or plowing under of all vines and rubbish in the fall. Close watch should be kept early in the season, when hoeing and thinning, for any appearance of the insect.

It is a small, green insect that attaches itself to the under side of the leaf. Close observation is necessary to discern it when it first appears. The insect secures its sustenance by sucking the sap from the leaf, and only contact remedies, such as kerosene emulsion, will be of service.

If but few hills are attacked, they may be destroyed, but this is not desirable. If the field becomes infested with this insect, spray the under side of the leaves thoroughly with the kerosene emulsion (diluted 30 times) to keep it in check. As soon as the melons are harvested, put in the plow with rolling coulter attached and turn the vines under deeply. Do not use the same land to grow melons the succeeding year.

Bulletin 63. April, 1901

The Agricultural Experiment Station

OF THE

Agricultural College of Colorado.

SUGAR BEETS.

A RÉSUMÉ OF THE WORK DONE BY THE AGRICULTURAL EXPERIMENT STATION OF COLORADO.

—BY—

WILLIAM P. HEADDEN.

PUBLISHED BY THE EXPERIMENT STATION
Fort Collins, Colorado.
1901.

The Agricultural Experiment Station

FORT COLLINS, COLORADO.

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INTRODUCTORY.

By the Director.

Since 1889 the Colorado Experiment Station has issued ten bulletins relating to sugar beets, eight of which have been devoted entirely and two partially to the study. Nearly all of these bulletins are now out of print, but demands still continue for the information contained in them. It is not desirable to reprint these bulletins, yet many of the investigations and conclusions are still pertinent, and it is believed that a summary of these bulletins to render the results accessible will be of much use, and incidentally serve to maintain the credit of the Station for the pioneer work on this subject which it has done in this State, the extent of which is realized by few. The bulletin places the facts developed in the published reports of this Station in compact form, and while attempting to summarize our own publications referred to, it does not attempt to summarize the work of the other stations or of the Department of Agriculture on the same subject.

This early and continuous work of the Station carried on since 1888, and supported in 1898, as it has been, by various interests, especially of the Denver Chamber of Commerce and the C. & S. R. R., has been an important factor in the location of the industry in Colorado on a firm foundation. These investigations have given the data necessary in order that sugar beet factories should be justified. At this time three factories (Grand Junction, Rockyford, and Sugar City) are in operation in the State. Another (at Loveland) is in active construction, and several more are in contemplation for 1902. The industry has every promise of being of much importance to the State, and especially valuable as it does not interfere with any other. The results already reached show that it finds in Colorado, as has been indicated in the early reports of the Experiment Station, a state well adapted to the industry.

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7. Potatoes and Sugar Beets. April, 1889. Profs. Cassidy and O'Brine.
11. Sugar Beets. April, 1890. Director Ingersoll and Dr. O'Brine.
14. Progress Bulletin on Sugar Beets. January, 1891. Dr. O'Brine.
21. Sugar Beets; Potatoes; Fruit Raising. October, 1892. F. L. Watrous.
36. Sugar Beets. March, 1897. Prof. Cooke and Dr. Headden.
42. Sugar Beets in Colorado in 1897. February, 1898. Prof. Cooke and Dr. Headden.
46. A Soil Study. Part I. The Crop Grown: Sugar Beets. June, 1898. Dr. Headden.
51. Sugar Beets in Colorado in 1898. March, 1899. Prof. Cooke.
57. Farm Notes. Alfalfa; Corn; Potatoes; Sugar Beets. July, 1900. Prof. Cooke.
58. A Soil Study. Part II. The Crop Grown: Sugar Beets. August, 1900. Dr. Headden.

PRESS BULLETINS.

1. The Sugar Beet Caterpillar. August, 1899. Prof. Gillette.
3. The Beet Army-Worm. May, 1900. Prof. Gillette.

Also, references in each of the thirteen Annual Reports of the Station.

SUGAR BEETS.

A RÉSUMÉ OF THE PUBLISHED WORK OF THE AGRICULTURAL EXPERIMENT STATION OF COLORADO.

BY WILLIAM P. HEADDEN, PH. D.

The first experiments made in the State of Colorado to determine the feasibility of growing sugar beets for the manufacture of sugar on a commercial scale were those made at the Experiment Station at Fort Collins in 1888. These were undertaken by Professors Cassidy and O'Brine at the instigation of the late C. L. Ingersoll, Director of the Station. Three varieties were experimented with. The percentage of sugar was quite satisfactory, the authors making the yield of cane sugar from 4,250 to 7,318 pounds per acre.

The object of these experiments is evident from the closing paragraphs of bulletin No. 7,* in which the work is recorded:

"From the above it will be seen that there is quite a wide variation in sugar content in the four varieties tried last season. Enough, however, has been developed to create a lively interest in the cultivation of the sugar beet in this State for the purposes of sugar production—"

From the publication of the results of these first experiments, in April 1889, to the present time, the Station has issued eight other publications on this subject, only one of which republished any of the results contained in previous bulletins.

The work on this subject has taken two directions, cultural and chemical. Bulletins 11, 46, and 58 are devoted to considerations of the latter class; Nos. 7, 14, 21, 36, 42, 51, and 57 almost exclusively to cultural studies, No. 14 alone deviating from this line in containing a statement of the Director and Chemist in regard to the state of the industry in 1890.

In No. 14 the question of the relation between the size of the beet and its sugar content was discussed, and the suggestion made that the size of the beets could be controlled by thick seeding and judicious thinning.

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* Potatoes and Sugar Beets. April, 1889. Profs. Cassidy and O'Brine.

The results given are uniform in showing that small beets, such as weigh from one to three ounces, are richer than large ones, thirty to forty ounces in weight, by two per cent. or more.

The conclusion of this bulletin indicates that the author had the general question of the adaptability of Colorado to the production of sugar beets in view rather than any cultural problem, for he says, "*We believe that it has been established that the soil and climate of Colorado are favorable to the production of sugar beets, and that they can be successfully and profitably raised to the advantage, both of the farmer and manufacturer.*"

Mr. Frank Watrous, in charge of the substation at Rockyford' grew beets in 1890, '91, and '92, and records the results of his experiments in bulletin No. 21. The season of 1890 was spent in groping after facts, and the product, though encouraging, was not large. The yield obtained ranged from eight to seventeen tons per acre. Some of these yields were from half acre plots, others estimated from single rows.

In 1891 an experiment in irrigating beets was made, from which Mr. Watrous concludes that, in an ordinary season, one irrigation during the growing season is sufficient to produce the best results both as to tonnage per acre and saccharine matter contained. Four plots of one-fourth acre each were planted to Vilmorin beets. Plot 1 was not irrigated; plot 2 was irrigated once; plot 3 was irrigated twice; and plot 4 was irrigated three times. The dates of irrigation are not given. The results are:

Plot 1. Yield: 9 tons per acre. Sugar: 14.25 per cent. Purity: 80.5 per cent.

Plot 2. Yield: 10.8 tons per acre. Sugar: 15.2 per cent. Purity: 84.3 per cent.

Plot 3. Yield: 9.9 tons per acre. Sugar: 14.22 per cent. Purity: 79.5 per cent.

Plot 4. Yield: 9.9 tons per acre. Sugar: 13.0 per cent. Purity: 76.0 per cent.

In 1892 the plots were 1-100 and ¼ acre each, four of the sixteen plots being ¼ acre in area. The yields from the ¼ acre plots were 18.7 tons, 20.5 tons, 25.0 tons, and 25.7 tons per acre, and the sugar percentage 15.18, 16.7, 15.9, and 18.9. The coefficient of purity was between 82 and 85. The yield from the 1-100 acre plots was somewhat higher, as was to be expected, the sugar content ranging from 13 to 15.8 per cent., and the coefficient of purity from 76 to 85.

The plan of culture adopted as the result of the three years' study is as follows: After land had been plowed, harrowed, and made quite smooth, even, and free from lumps, stones, or trash, seed

was sown with an ordinary hand drill, sowing eighteen pounds to the acre, covering an inch or less in depth, in double rows one foot apart, separated by a space two feet wide. Then, with one horse and a shovel plow, a trench was made in this space, the dirt being thrown on both sides to finish covering the seed. The rows are worked over quickly with a rake or hoe, and the seeding is complete. Beet seed requires considerable moisture to produce germination, hence, in a dry spring, water may be turned in these ditches and beets brought forward, independent of dry weather.

To facilitate irrigation, rows should not be more than three hundred feet in length, preferably less. It should not be necessary to drench the upper end in order to moisten the lower end.

Proper cultivation consists in hand hoeing or working with a fine-toothed cultivator, the surface of the ground being stirred as soon after irrigation as practicable. From experience at this Station it seems safe to state that the more careful cultivation, with the proper amount of water when needed, the more sugar per acre.

Bulletin No. 36 discusses the general outlook for the sugar industry in Colorado. The question of market for the sugar which might be produced in the State is answered as follows: "To produce the sugar consumed by the inhabitants of Colorado would require five factories of large size, employing two hundred men each, who, with their families, would represent about four thousand people. It would require the growing of sugar beets on fifteen thousand acres of land, and add more than three hundred dollars to the income of each of two thousand farms."

Touching the question of profit, the writer says: "*If prices are such as to make the business profitable anywhere, then it will pay in Colorado.*"

The irrigable portions of Colorado below 5,000 feet in altitude and east of the Rocky Mountains, possess the best possible climate for the growth of sugar beets, as do many of the valleys of the western portion of the State, but the parks of Colorado are too cold for the sugar beet to be grown with profit.

The common cause of failure among beginners is a lack of thorough preparation of the soil. The plowing should be done in the fall, subsoiling to fifteen or eighteen inches. If this is done, a thorough harrowing just before planting will be all that is needed.

If the plowing is done in the spring it should be delayed until just before planting. The planting is done with a drill. An ordinary wheat drill may be used, but there are special drills for planting beets. Twenty-four inches is recommended as the distance between rows, being none too far apart for irrigation.

The quantity of seed recommended to be sown is at the rate of twenty pounds to the acre. This quantity is large, but advisable in order to get a full stand. The seed should be put in about an inch and a half deep. If the ground is thoroughly wet at the time of planting half an inch may suffice. If the plowing is done in the spring it may be advisable to irrigate the ground thoroughly before plowing, and thus insure a good supply of moisture in the subsoil.

If, after the seed is sown, the weather is so dry that the seed has to be "irrigated up," the chances of a profitable crop are slight. The seed can be successfully "irrigated up" by running a furrow six inches from the drill and allowing a small head of water to run until it has wet the seed by soaking sideways.

The planting may be done from the last of March till the middle of June. Sugar beets sown the first of May will be ready for harvesting about the first of October.

The first cultivation should take place as soon as the plants are up enough to enable one to follow the row. Whatever implement is used, it should merely scratch the surface of the ground, leaving it level and killing the small weeds without throwing dirt onto the young plants. The weeds must be kept down. The ground should be cultivated after each irrigation to level the ground and make a dirt mulch on top to preserve the moisture.

The beet crop in Colorado will need one, and possibly two or three, irrigations. The last irrigation should be given about six weeks before the crop is mature.* In 1895 a heavy rain in September kept the beet crop in full growth until frost, and produced a crop with much less than the usual amount of sugar.

The plants should be thinned when they have four leaves, leaving but one plant in a place. The distance between plants should be eight to ten inches. There is generally but little difference in the weight of the crop in cases where the beets stand six, eight, and ten inches apart. It is easy to grow beets weighing five pounds each, where the soil is rich, by thinning to twelve inches, but such beets are inferior to beets averaging less than two pounds for sugar, and also for stock feeding.

In thinning, the plants are cut out by means of a sharp hoe, leaving bunches of a few plants each, which must be thinned to a single plant by hand.

The soil of Colorado is generally rich enough to grow several crops of beets without fertilizing, but it must eventually be fertilized in order to maintain the yield.

* This is a general statement, and must be deviated from in special cases.—H

In case alfalfa ground is broken up beets should not be grown on it the first season, but rather a crop of wheat. This will put the soil in better condition and will rot the alfalfa roots. It is not advisable to grow beets more than two years in succession on the same ground.† Alkali ground may be an exception.

If barnyard manure is used to fertilize the soil, the beets can advantageously follow a crop of corn.

The best varieties are the Kleinwanzlebener and Vilmorin.

The harvesting is done either by means of a beet puller or by plowing a furrow near the beets and pulling them by hand.

The topping is done by means of a heavy knife. Topping machines have, as yet, not been successful.

The factories work on beets hauled directly from the field up to the time freezing weather sets in. Beets to be used in the later part of the season should be protected from freezing; for this purpose they may be put into shallow pits and covered with straw and dirt, either near the factory in pits provided by them, or in the field.

The cost of growing an acre of beets varies in different parts of the country, the size of area planted, the condition of the ground, etc. The range is from thirty to forty-five dollars, or from two to four dollars per ton.

About eleven tons of sugar beets per acre at four and a half dollars per ton is a fair average crop, with a possibility of a much larger yield. Compared with alfalfa or wheat, the return seems large, but much more labor is required to produce it.

Sugar beets have a high value for stock feeding. They have been fed at the College with good results, except where fed to steers. The beets seem to be too watery for profitable feeding to steers where the feeding is done out of doors in cold weather. It is advisable not to feed them to fattening lambs for the last six weeks before marketing, grain being preferable at this period, so that the flesh and fat may harden for shipment.*

The tops are good feed for all classes of farm animals. They may be fed at once, as soon as harvested, or put in a silo and fed through the winter.

The next record of results occurs in bulletin No. 42. In 1897 we made an effort to enlist persons in different parts of the State in the raising of sugar beets. The Station has already established beyond any doubt the adaptability of both the soil and climate of this

† Without fertilization.

* The author does not make any statement as to the extent to which grain should replace the beets at this period, whether wholly or only partially.—H.

section of the State to the cultivation of the sugar beet, and also of that of the Arkansas valley, where the substation at Rockyford is located, but no co-operative work, including all sections of the State, had been entered upon. The Station received from the Department of Agriculture at Washington, five hundred pounds of beet seed, and from A. Keilholz, Quedlinburg, Germany, two hundred pounds. This seed was sent to six hundred and eleven persons residing in in forty-seven counties of the State. Most of the analyses of these beets were made by the Department of Agriculture in Washington. The State was divided into five sections, as follows:

1. The valley of the South Platte and its tributaries.
2. The Divide south of Denver, where crops are raised without irrigation.
3. The valley of the Arkansas.
4. The valley of the Grand.
5. The San Luis valley.

The varieties used were the Kleinwanzlebener, Vilmorin, and the Imperial White. As there were one hundred and six samples of the Kleinwanzlebener variety out of the one hundred and twenty-five recorded, no distinction is made between the varieties in this summary.

The percentage of sugar in the samples from the Platte valley ranged from 11.5 to 20.0, the coefficient of purity from 73 to 86, and the crop in tons from 9 to 47.

The percentage of sugar in the samples from the Divide section, grown without irrigation, ranged from 11 to 18, the coefficient of purity ranged from 71 to 87, and the yield in tons from 9 to 22.

The percentage of sugar in the samples from the Arkansas valley ranged from 12 to 20, coefficient of purity from 73 to 86, and the crop in tons from 12 to 40.

The samples from the Grand valley showed percentages of sugar ranging from 12 to 19, coefficients of purity ranging from 74 to 86, and crops from 15 to 42 tons.

The samples from the San Luis valley * showed percentages of sugar ranging from 11.5 to 17.9, coefficients of purity from 74.2 to 86.9.

The time of ripening of beets in Colorado will vary, of course, but the average of the samples taken between September 25th and October 10th is 14.1 per cent. sugar and 80.7 per cent. purity, which is an excellent grade of beet. To get the crop to ripen is the principal aim of the beet grower. The most important factor in this is

* Altitude 7546 feet.

that the beet shall be kept growing all the time from the sprouting of the seed until the harvest. Some of the conditions on which the ripening of the crop depends are beyond the control of the grower. In Colorado it is true in general that the crop will not ripen until the vigor of growth has been checked by frost. The best means of determining whether a crop is ripe or not, that is, in condition to go to the factory, is by means of an analysis, but a good judgment can be formed by cutting a beet and noticing the rate at which the cut surfaces darken.

The increase in percentage of sugar and coefficient of purity during ripening is about three per cent. for the former and about five per cent. for the latter.

Some very suggestive facts relative to methods of culture were observed during this year's study. Certain principles of beet growing have come to be considered as essential to the production of the best beets. These principles were violated by most of the growers of beets this year, it being their first experience, and yet they obtained good results. It is said that beets should never be planted on new ground. This was violated with good results, giving, in one case, beets of 15.2 per cent. sugar and 82.4 per cent. purity, and in another 19.4 per cent. sugar, and in others the beets were above the average. Ground which had been broken but one year gave uniformly good results. So, too, in regard to time of plowing and subsoiling. All writers on sugar beet culture agree that beets should not be planted on ground that has been recently manured. Sixteen persons report manuring with stable manure. The crops were late in ripening, but with three exceptions, the quality was good. The results as a whole indicate much more gain than loss from the application of stable manure.

The hardest part of beet raising is to get a full stand all over the field. The poor growth of the seed is due to lack of moisture, too deep planting, and poorly prepared ground. The lack of moisture can be overcome in two ways—by irrigating before or after planting the seed. The latter seems to be more promising as a general method. Of fifteen persons trying this method, eight report having obtained a thick stand, being twice as large in proportion as those reporting a thick stand by depending on rain or the original moisture in the ground.

Mr. Geo. H. West, of Greeley, contributed an interesting article, published in bulletin No. 42, containing the observations and conclusions of his study of the subject, which he designates "Growing Sugar Beets for Factories." Mr. West studied this subject in Nebraska, Utah, and New Mexico. Of the growing of beets in Nebraska he says: The farmers are largely Germans, with some Rus-

sians. Women and children work with the men in the fields. Where a large acreage is in beets, the thinning, weeding, hoeing, pulling, and topping is done by contract. Laborers receive from fifteen to twenty dollars per month, the usual wages by the day being one dollar and board. On contract work the rate is from fifty cents to one dollar for boys; one dollar for men and women, without board. For a man and team, two dollars and fifty cents per day; for man and horse, one dollar and seventy-five cents. Land rent from three dollars and fifty cents to six dollars per acre.

The average yield in 1897 was 7.25 tons, and the sugar extracted by the factory at Norfolk was 10.95 per cent. The percentage of sugar in the beets was 13.1 per cent., purity 81.5 per cent.

The Grand Island beet raisers averaged 8.1 tons per acre. The average percentage of sugar in the beets in 1897 is said to have been 12.87, and purity 79.5. The percentage of sugar obtained from these beets by the factory was 8.72.

The tables given show that in 1897 the factories at Norfolk and Grand Island treated the largest tonnage and made the highest saving attained up to that year. The range of farm wages is from fourteen to twenty dollars per month, with board; and from one dollar to a dollar and a quarter by the day. Women and children generally work on the contract plan. Many girls get a dollar a day in the beet fields, and prefer it to house work. Boys from ten to eighteen years of age receive from fifty to eighty cents per day, a man and team two dollars and fifty cents, and a man and horse one dollar and seventy-five cents per day. Contracts can occasionally be made, as in Colorado, at two dollars per day for man and team. Land rentals range from four dollars to seven dollars per acre. The crop of 1897 is said to have been reduced fully one-third by drought. No beets are grown by irrigation in Nebraska.

At Lehi, Utah, the conditions are said to be ideal for the growing of beets and running a sugar factory. The farms vary from five to forty acres in extent, and fully nine-tenths of them are worked by the owners. Mortgages are rare and the farmers prosperous. The women do not work in the fields, and the girls seldom work there unless at home. Much of the hand labor is done by boys. The average acreage per grower is less than four acres. The highest average yield per acre was in 1896, 13.5 tons. The average per acre from 1891 to 1897, inclusive, was 9.44 tons. The highest average percentage of sugar in the beets was, in 1896, 13.9 per cent. The average percentage from 1891 to 1897, inclusive, was 12.4 per cent. The average percentage of sugar extracted, 1891 to 1897 inclusive, was 8.46. Land rentals range from $7.50 to $15.00. The soil shows a

great diversity about Lehi, but is generally a heavier soil than the uplands of northern Colorado.

The Eddy, New Mexico, sugar beet factory has been run for two seasons only, 1896 and 1897. The valley, though a natural fruit garden, lacks the farming population, and pernaps, too, the close, careful cultivation and knowledge of irrigation of the older farm districts of Colorado. In 1897 they grew 1,900 acres of beets; yield, three tons per acre; percentage of sugar, 14.2; purity, 80 per cent.; percentage of sugar extracted from the beets, 10.53.

The average cost of growing and delivering a crop of beets at Norfolk, Nebraska, is $26.50 per acre; the average profit, $11.04. The yields range from five to fifteen tons per acre. The net returns vary from a profit of $29.00 to a loss of $7.55 per acre. At Grand Island, Nebraska, the average was $28.73 per acre, and the average profit $9.27. The yield varied from five to twelve tons per acre, and the net results from a profit of $17.00 to a loss of $12.00 per acre. Mr. West puts the average cost of growing and marketing sugar beets in Nebraska at $30.00 per acre, and states that the officials of both factories put it at the value of seven tons of beets, or $28.00.

The average cost of growing beets in Utah, not including land rentals, is put at $32.50 per acre. The average yield is stated at 10.1 tons, but the yield for 1897 was 6.75 tons. Improved beet cultivating implements had not, at that time, been introduced into Utah, and this, with the higher land rental and cost of irrigation, raises the actual cost to probably $40.00 per acre.

Relative to the profits of beet culture, Mr. West says: Large yields are regularly obtained by those farmers who do thorough, clean work, and intimates that therein lies a big secret of success.

It is also pointed out that the labor question is a most serious problem in this industry. It is too important to be entirely passed over, even in a summary such as this.

Concerning the feeding of pulp to cattle and sheep he gives results obtained in Nebraska and Utah. At Lehi the pulp is placed in silos with addition of about one-half per cent. of its weight of salt. The cattle always have access to plenty of hay, pulp, and water. *They never feed a pound of grain in fattening the stock,* unless the pulp gives out.

John Reimers, Grand Island, Nebraska, had had three years' experience in feeding pulp to cattle. He fed fifty pounds of pulp, twenty pounds of corn meal, a little bran, and oil cake, and the usual amount of hay per day, as a full ration. Hake Bros., also of Grand Island, fed lambs a mixture of four pounds of pulp to one or one and a half pounds of corn meal, besides hay, as a full ration.

The results are highly satisfactory. The pulp is said by Superintendent Geo. Austin, of Lehi, to give the best results after fermenting in the silos for thirty days, and should not be fed sooner than this.

The experiments made in 1898 are grouped as follows in bulletin No. 51:

1. *Different dates of planting.* Results in favor of early planting in respect to yield, sugar content, and purity.

2. *Planting on freshly plowed ground as compared with planting on ground plowed a few days before planting.* Resulted in favor of planting on freshly plowed ground by 2.3 tons in yield, two per cent. in purity, and a slight excess in sugar.

3. *Seed irrigated at planting as compared with that not irrigated.* Results obtained on the College Farm showed no advantage from this practice. The soil was a rather heavy loam and was moist at planting time. Good results have been observed from this practice on lighter soils.

4. *Soaking seed before planting.* Results did not show any gain from the soaking of the seed.

5. *Sowing at the bottom of a three-inch furrow.* The resulting stand was not so good as that obtained by sowing at ordinary depths. The yield was once as good and twice poorer than that from similar rows of ordinary planting. The percentage of sugar and purity were not perceptibly different from other plantings.

6. *Different depths of planting.* The depths at which the seed was planted were from one-half an inch to an inch and a half. The first series, planted May 11th in a wet soil, showed no difference, but the later planting, made May 27th when the soil had dried out considerably, showed an advantage in favor of the deepest planting, amounting in comparison with the shallower plantings to more than one-third of the crop. The stand, yield, and quality were all better than in the cases of shallower planting.

7. *Transplanting.* Transplanted beets are usually ill-shaped. The yield may be good, percentage of sugar and purity high, but the method would not be a financial success.

8. *Different distances of thinning.* The results obtained show that the distance apart of the beets, from four to ten inches, has but slight influence on the quality of the crop as to sugar and purity. In a general way the thicker stand tends to a larger yield, but there are exceptions to this statement.

9. *Different dates of thinning.* The results show that the

thinning of beets can be extended over a period of two weeks without injury to the crop.

10. *Variety tests.* Six varieties, Zehringen; Vilmorin's Improved, grown in Russia; Kleinwanzlebener, grown by Vilmorin; Pitschke's Elite; Vilmorin's French, very rich; and Schreiber's Elite were grown side by side with Kleinwanzlebener, strain not given, with almost identical results in percentage of sugar and purity, the sugar ranging from 15 to 17.20 per cent., and the purity from 76 to 81.9. The average of all the samples analyzed in this test is 16.04 per cent. sugar, and 78.9 purity.

11. *Number of irrigations.* At Rockyford, beets were grown without irrigation, with one, and with four irrigations. This experiment was of little value, being defeated by the unusually heavy rains of that season.

At Pueblo, Mr. C. K. McHarg applied water to one-half of some experimental plots twice after the 20th of August, the other half receiving none after that date. The two later irrigations produced an increase of one-seventh in the weight of the crop, and the percentage of sugar was increased; beets from the half irrigated late, contained 16.42 per cent. sugar, 81.0 purity, and those from the other half contained 15.79 per cent. sugar, 81.7 purity.

12. *American grown seed vs. imported seed.* Two samples of American grown seed were used, one grown in Utah and the other in New Mexico, both were strains of Kleinwanzlebener beets. The imported seeds were the Original Kleinwanzlebener, Vilmorin, Mangold, and Elite Kleinwanzlebener.

The Elite Kleinwanzlebener and the Vilmorin were sent us by the U. S. Department of Agriculture as the best beet seed that they could get. The Original Kleinwanzlebener was selected by the Utah Sugar Company as, in their judgment, the best brand of seed on the market from which to raise their own seed. The Utah grown seed produced as large a crop and one richer in sugar and purity than the average of these three. It excels its parent strain in richness and purity, and is but little inferior in quality of crop.

The New Mexico seed equals the Vilmorin and is not far behind the original Kleinwanzlebener.

The germinating quality of the seed is quite satisfactory.

In 1899 the questions whose solution were attempted were:

Does it pay to subsoil? The results of ten tests made at this Station show an average gain of 18 per cent. in the weight of the crop as the result of subsoiling.

Is it advisable to plant the beet seed very early? The average

crop from ten plots sown between April 10th and 20th was 27.7 tons; from ten plots sown between May 1st and 10th was 24.3 tons; from ten plots sown between May 15th and 26th was 20.4 tons; and from ten plots sown between May 31st and June 10th was 15.3.

The percentage of sugar in these various crops scarcely differed at all, 0.76 of one per cent. being the maximum difference, and 3.2 was the maximum difference in purity. The difference in crop, however, is very decidedly in favor of very early planting.

The question of the distance between rows is recurred to again, and a former recommendation is repeated, *i. e.*, making the alternate spaces between rows narrower and wider. The distances advocated are eleven and twenty-seven inches. The chief advantage claimed is in irrigating, also an increase of crop.

IRRIGATING UP THE SEED.

Twelve experiments were made with irrigating up the seed, and a like number without irrigation. Of the twelve experiments with irrigation none failed, of those without irrigation two failed. The crops from the twelve irrigated at the time of planting averaged 26.3 tons to the acre. The crops from the ten plots which came up, but which were not irrigated at the time of planting, averaged 25.4 tons to the acre.

INSECTS INJURIOUS TO BEETS.

The earliest observations on this subject seem to have been made by Prof. C. P. Gillette in 1894, when he records the leaf hoppers *Gnathodus abdominalis*, *Platymetopius acutus*, and *Agallia uhleri*, as doing injury to beets in the vicinity of Grand Junction, also a mealy bug, *Dactylopius solani*, as infesting the crowns of the plant. The next mention of injury to beets by insects is in 1897, when the writer's patch of beets was seriously injured by the leaf hoppers *Agallia uhleri*, *A. sanguineolenta*, *A. cinerea*, and the striped beetle *Systena taeniata*. Later *Monoxia puncticollis*, and also the blister beetle, *Macrobases unicolor*, did some damage.

In 1899 the beet army-worm (*Laphygma flavimaculata*) made its appearance near Grand Junction, and was very destructive. It did not appear in injurious numbers in this locality in 1900. Prof. Gillette and his assistant, Mr. E. D. Ball, found but few specimens of either the first or second brood. Prof. Gillette (Thirteenth Annual Report of the Colorado Agricultural Experiment Station) says of this failure of the insect to appear the second season: The very sudden appearance of this insect, which had never before been considered injurious, in such destructive numbers, and its equally sudden disappearance, is quite remarkable. Particularly is this so from the fact that the fall brood of worms in 1899 were but little parasitized, and the moths matured in enormous numbers. The latter

must have failed, for some reason, to winter over. These worms appeared on some experimental patches of beets at Lamar and Rockyford in 1899, and the first brood appeared in destructive numbers in 1900. The worms began to appear during the first week in June, and were abundant by the 14th, when spraying was begun. Late planted beets were not injured by them, except where they were planted near patches of weeds or earlier beets. The poisons were effectual, especially where two sprayings were made with Paris green.

Other insects mentioned by Prof. Gillette as having been observed on beets and not already mentioned, are *Nysius angustatus* (often called false cinch bug), more or less abundant everywhere, in some cases causing beets to wilt and die. *Deilephila lineata* was found as an occasional feeder, especially where purslane was allowed to grow. (Mr. Ball's notes.)

Chemical Considerations, Bulletin No. 46.

THE EFFECTS OF ALKALI.

Sodic carbonate, or black alkali, when present in quantities equal to less than 0.1 per cent. of the weight of the dry soil, does not prevent a satisfactory germination, but a still smaller quantity, as little as 0.05 per cent. of the weight of the dry soil, will corrode the plants, both plumule and radical, causing their death. We have occasionally observed corroded plants in alkali ground, but in spots only. The ground experimented with was very strongly alkalized, the worst, in fact, that we had at our disposal.

Sodic sulfate, or white alkali, does not prevent germination when present in quantities equal to less than 0.70 per cent. of the weight of the dry soil. No corroding by this salt has been observed.

The effect of the black alkali, sodic carbonate, is not mitigated by the presence of the white alkali. The sodic salts hasten germination by 36 to 48 hours.

Magnesic sulfate, one of the constituents of our alkalies, retards but does not prevent germination.

The beet plant can endure a larger amount of white alkali in the soil after it has become established.

Alkalinity of soil did not effect date of ripening in a series of experiments made at the Station.

Alkali does not affect the sugar content of beets grown on soil in good, or even fair tilth.

The ripening of beets may be seriously affected by a rainfall, or untimely irrigation. The crop of 1897 showed this plainly. On September 8th the beets had already begun to ripen, from the 10th to the 14th, 0.74 inches of rain fell; on September 22nd the samples analyzed showed a lowering in the percentage of sugar present. This loss was not regained for nearly three weeks, the beets, however, increased greatly in size during this time.

The ripening in this case took place more suddenly than is probably usual, and corresponded to an increase of from 2 to 3.5 per cent. in the different plots and is equivalent to about one-third of the total yield of sugar—that is, if the yield of sugar be 6,000 pounds per acre, 2,000 pounds is formed during the period of ripening.

Beets were covered with straw and left undug until January 7, 1898, with a slight gain in percentage of sugar and purity, showing that beets under favorable conditions may remain unharvested without loss of sugar or weight of crop.

Distribution of the sugar in the beets. In bulletin No. 11, it is stated that the amount of sugar increases in the successive sections of a beet from the top downward. This is not sustained by bulletin 42, which shows that the upper third, including the crown, contains only about 0.2 of one per cent. less sugar than the lower two-thirds, and these, the lower two-thirds, cannot be said to differ at all; sometimes the second and sometimes the third third having the higher percentage of sugar, the difference always being so small that it is insignificant.

SUGAR IN THE CROWNS.

The crown as used in bulletin No. 42, is really a structural portion of the beet, and not any indefinite portion which may have chanced to grow above the ground. It is very rarely the case that sugar beets, Kleinwanzlebener or Vilmorin, grow above ground at all with us. The difference between the sugar content of the crown and the beet from which it is cut is about one per cent. The coefficient of purity is lower than that of the beet, but not necessarily poor. The example given shows beets 16.1 per cent. sugar, 88.0 purity; crowns 15.1 per cent. sugar, 82.4 purity.

EFFECT OF FREEZING ON BEETS.

Simple freezing does not cause any change in the sugar. If thawing can be prevented the crop is not necessarily lost if frozen.

DRYING OUT OF BEETS.

This takes place rapidly if the beets are exposed. Beets wrapped in paper and placed on the earth of a cellar bottom lost about five per cent. of their weight during the first twenty-four hours; from this the daily loss fell to about two per cent., at which rate the beets continued to lose up to the seventeenth day. The percentage of sugar increased.

The drying out of beets has another effect, it is accompanied by a loss of sugar. This loss varied in the experiments recorded from one-fortieth to one-sixth of the sugar present.

The suggestion is made that the loss may be materially influenced by the condition of the crop, the loss being greater in unripe beets than in riper ones.

The yields recorded range from 7.9 to 11.8 tons per acre for sugar beets, and 15.9 tons per acre for Lane's Imperial.

The ratio of the weight of the tops to that of the beets was found in two ways. First, weighing the carefully removed tops and beets gave for sugar beets of different varieties ratios varying from 1:1.087 to 1:1.274, or the weight of the tops varied from 78.5 per cent. to 92.0 per cent. of the weight of the beets. The second method was to weigh the beets as harvested and the tops as removed from them. On removing these tops no part of the crown of the beet was taken. The result was that we found the ratio to be 1:1.14. The general ratio obtained by the first method was 1:1.12. The weight of leaves as harvested in the field equalled 87.7 per cent. of the weight of the roots. The results obtained in the laboratory gave their weight as equal to 89 per cent. of that of the beets.

The tops of beets grown on alkalized ground were relatively a little heavier than in cases where the ground was practically free from alkali.

The tops increase but little in weight during the last six weeks of the growing season. The beets, on the other hand, gained 64 per cent. of their weight at the beginning of this period.

The beets ripened this season, 1897, the second week in October, and about one third of the total crop of sugar was deposited during this period.

The percentage of dry matter in sugar beets increases with the maturing of the beet. In green beets harvested September 2nd we found from 8.8 to 14.6 per cent., with an average of 12.1 per cent. In mature beets it ranges from 17.0 to 20.5 per cent., and in exceptionally favorable seasons it may be higher. Sugar forms a larger percentage of this dry matter in mature beets than in green or immature beets.

There is a little more dry matter in the top one third of the beet than in the other two thirds.

Stock beets contain less dry matter than sugar beets. We found the dry matter ranging from 12.25 to 14.63 per cent. in mature beets.

The marc or pulp, the portion left after the sugar and soluble matters have been washed out, ranged from 4.21 to 5.25 per cent. The average is about five per cent.

For fodder analyses of sugar beets grown on alkali soil and soil free from alkali, of stock beets, beet tops, and marc or pulp, see bulletin No. 46, page 37.

Alkali in the soil tends to increase the percentages of ash and albuminoids.

The feeding value of dry pulp may safely be estimated as equal, pound for pound, to the dry sugar beet.

One ton of sugar beets yields about four hundred pounds of dry matter, and only one hundred pounds of dry pulp. One ton of stock beets yields about two hundred and forty pounds of dry matter, which is richer in albuminoids and nitrogen-free extract than the pulp is; the pulp, however, is a by-product and the stock beets are not.

The percentage of crude fiber in beets is quite irregular, but uniformly higher in beets from alkalized ground than others.

Alkali affects the composition of the beets more than that of the leaves.

The percentage of ash in the beet ranged from 0.79 to 1.33 per cent. in immature beets, samples harvested September 2nd, to from 0.95 to 1.39 per cent. in mature beets harvested October 13th. The average is 1.10 per cent. of ash in the fresh beet.

Fifty-eight per cent. of the total ash constituents removed from the soil by the roots, and 70 per cent. of all the mineral constituents removed by the leaves, had been gathered by September 2nd. The accumulation of ash constituents continues until the period of ripening.

The slight decrease in the percentage of ash as the roots approach maturity is due to the rapid increase in the weight of the beets. There is no diminution in the amount of ash constituents in the crop.

The influence of alkali, present in large quantities, is to increase the ash by about two per cent., reckoned on the dry matter.

The ash is quite evenly distributed throughout the beet, with a slightly larger amount in the top one-third, but the percentage of ash is higher in the dry matter of the bottom third.

The ash of the beet has a pretty uniform composition, generally showing about 3.5 per cent. sulfuric acid, 7 to 9 (usually about 8.5) per cent. phosphoric acid, 48 to 52 per cent. of alkalies, 2 to 3 per cent. of lime, about 6 per cent. of magnesia, 11.5 to 14.5 per cent. of chlorin, and about 15 per cent. of carbonic acid in the fine ash. When the carbonic acid is higher than 15 per cent. either the phosphoric acid or the chlorin is correspondingly lowered.

The composition of the ash of the leaves is quite different from the composition of the ash of the roots. The ash of the leaves contains from 3.5 to 3.9 per cent. of sulfuric acid, 1.8 to 2.3 per cent. of phosphoric acid, 23.7 to 25.7 per cent. of potash, 22.3 to 25.5 per cent. of soda, 1.5 to 2.5 per cent. of lime, 6 per cent. of magnesia, 23.3 to 28.5 per cent. of chlorin, and from 10.6 to 15.0 per cent. of carbonic acid.

The composition of the ash of immature beets is the same as that of mature beets. The only exception to this statement seems to be the percentage of chlorin in the ash of the leaves, which increases so generally and uniformly that it suggests a relation between the degree of maturity and the quantity of chlorin.

The soil, repeatedly referred to as alkalized, contained chlorid of sodium, or salt, equal to 0.025 per cent. of the weight of the air dried soil. This gives us 2,800 pounds of salt in each acre of soil, taken to a depth of two feet. The total water soluble in this soil varies from 0.09 to 1.4 per cent. of the weight of the air dried soil, taken also to a depth of two feet. The higher figure gives us the immense quantity of 49.0 tons of alkali per acre, consisting of 16.33 tons of sodic sulfate, 17.64 tons calcic sulfate, 10.27 tons of magnesic sulfate, and 1.25 tons of ordinary salt.

Continued cropping to beets would soon show a perceptible reduction in this quantity of sodic chlorid, especially if the leaves were carefully removed, but the ground water is rich in salts, and is capable of replacing this, as well as the other "alkali" salts removed.

Stock beets, including leaves, remove, crop for crop, more soda salts than sugar beets do, but not ton for ton.

The chemical work of 1898 and 1899 is recorded in bulletin No. 58, which continues the study of the effect of soil conditions on the stand and quality of the beets, and the chemistry of the beet itself.

There were certain spots in which the seed failed to germinate, and the cause of this was not discovered. It was not explained by either a lack or an excess of moisture, nor was the alkali as excessive as in some other places.

The plot experimented with was the same as that used in 1897, the results of which appear in bulletin No. 42.

The rainfall for the months of July, August, September and October was 2.8 inches, the total amount received by the crop from the time of planting till harvested was about eight inches. The ground at the time of planting was wet, and the water plane was about two feet below the surface. The water fell about a foot in the next thirty days. An irrigation given July 8th to 11th did not suffice to raise the water to its earlier level, and it fell two feet in eleven days. The level of the ground water was not sensibly affected two hundred feet east of my plot by this irrigation. The water plane fell slowly from July 25th until early in October, when it reached its lowest point. The water plane from July 15th to October 10th ranged from three to four and one half feet below the surface at the east end of the plot, and there were but few beets in this section. At the upper and higher end of the plot the plane varied from 5.2 to 6 feet below, and the crop was excellent. In an intermediate section the water plane varied from 3.5 to 4.5 feet below the surface, with an abundance of alkali, and it yielded a good crop. The crop showed the need of water during the later part of the season, notwithstanding the high water plane. The ground had been kept as mellow as possible, and clean, having received five hoeings and five cultivatings. This plot of ground was put in beets in 1899, and needed no irrigating, it having been sub-irrigated this season from higher ground lying to the west of it. The wetness of the ground interfered with the cultivation of the crop, but the mechanical condition of the soil was so much improved over that of previous years that the cultivation was much easier. In 1899 this plot was soaked, August 31st to September 2nd, and the crop left to itself. The crop from this plot in 1897 was, taking an average of all varieties of sugar beets, about nine tons; in 1898, thirteen tons; in 1899, fourteen and one half tons to the acre. The increase in the crop is due to the betterment in the condition of the soil and a rather better stand.

Application of manure, sheep manure in this case, improved the stand by at least ten per cent.

The ripening of the crop of 1898 was entirely different from that of the crop of 1897. In 1897 there was a rainfall in September, on the 14th, which interrupted the ripening. In 1898 the crop developed continuously up to maturing. No sudden increase in the percentage of sugar was observed as in the preceding year, when the

increase was from 2 to 3.5 per cent. In 1898 the greatest gain observed, which could be attributed to ripening, was 1.4 per cent. The varieties grown by the Farm Department remained almost constant from October 3rd till October 22nd, in only one variety was there a gain of as much as one per cent. The ripening of the crop is much more gradual some seasons than others. The same observations were made in regard to the effect of the alkali upon the quantity of sugar, coefficient of purity, and time of maturing as were recorded in bulletin No. 46, namely, that the effect of the alkali is not detrimental.

The effect of the manure upon the sugar content and coefficient of purity, considering all of the tests, which, however, are not concordant with one another, is to lower both the sugar content by from 0.5 to 1.2 per cent. and the coefficient of purity by from 0.1 to 3.1 per cent.

The effect of the manure on the shape of the beet was bad, and this effect was uniform in the six comparative experiments which were conducted.

These effects of the manure were noticeable the second year after its application, but not in so marked a degree as they were the first year.

The result the second year is probably due to the failure of the manure to thoroughly rot and become incorporated with the soil.

Cut straw was also used as a dressing. Its effects were beneficial to the soil, but less in degree than those of the manure. Its effects upon the beets were not pronounced enough to permit the expression of a positive judgment. The results of this experiment are taken as corroborative of the opinion expressed elsewhere, that it is the mechanical condition of our alkali soils that preeminently needs improvement. That section of the plot which has been in the worst mechanical condition shows more alkali on the surface than the others. The water soluble in the soil, however, is greater in other portions of the plot. No attempt is made to formulate the relation existing between the mechanical condition of the soil and the amount of alkali present. These two factors are spoken of together as producing certain effects on the crop, but the opinion is expressed that the alkali, *per se*, is not the cause of these effects. This opinion is based upon the observation of spots where there is an abundance of alkali, but where the mechanical condition of the soil is better. No statement is made as to the extent of the influence of the alkali upon the mechanical condition of the soil. This point is left as an open question. The crops have improved each year, showing a mitigation of these conditions due to cultiva-

tion. This improvement is not due to drainage, for the water table has not been lowered and is seldom low enough to prevent capillarity from bringing moisture, and consequently salts, to the surface. An attempt was made to determine the direction and rate of the flow by introducing lithia salts into one of the wells, but it was found upon examination that the ground water contained lithia at all times.

The effect of seasonal differences upon the crop was noticed in the greater amount of dry matter in the beets in 1898 than in 1897. The difference in the percentage of dry matter attributable to the seasons was from 3.0 to 3.75 per cent., about one sixth of the total dry matter in the beets.

The question of the rate of drying out was taken up again with more care than in previous years, with about the same results, *i. e.*, that the loss for the first twenty-four hours was about five per cent. In this case, with a temperature of 57 to 66 degrees, the loss was 4.39 per cent. It fell to two per cent. in a few days, and remained at this figure for twelve days. The effect of drying out is shown in its effect on the average sugar percentage in 1898. In this year we analyzed 813 samples. The average percentage of sugar is found to be 15.12, without making any allowance for the drying out. We succeeded in obtaining fairly reliable data in 336 instances on which to base the deduction which should be made, and find it to be 1.5 per cent., which gives us an average of 13.62 per cent. for the crop.

The conclusions arrived at, as the result of many experiments to determine the relation existing between the size of the beets and their sugar content, are: That beets to be compared must be grown under the same conditions; that the conditions determining the percentage of sugar are so complex that no given weight can be accepted as a limit which, if exceeded, will indicate that the beet is not of proper richness and quality for the manufacture of sugar; that when the large size is due to an excessive supply of plant food, or an unduly large feeding ground and a constant and very abundant water supply, the beet is quite certain to be low in sugar, but this will be true of all beets, large or small, grown under such conditions.

Eight experiments, in which beets weighing less than one half a pound are compared with beets weighing more than two pounds, showed that the smaller beets were richer in seven instances and poorer in one. The maximum difference in favor of the smaller beets is one per cent., the least difference is 0.19 per cent. The average difference is 0.50 per cent. The beets above one half pound in weight make the crop. The coefficient of purity is better in the

larger beets, or at least as high as in the smaller ones. The conclusion drawn from another experiment is that too great a width between the rows tends to have the same effect as permitting beets to grow singly.

In 1898 it was observed that certain over-irrigated spots had turned yellow. Analysis showed that these beets were richer in sugar than the beets growing adjacent to them, but which had not been over-irrigated, by upwards of three per cent., and the coefficient of purity was much better, ten per cent. This clue was followed in 1899 with excellent results. The average percentage of sugar for beets grown by the Chemical Department in 1898 was 13.65. The average for all samples analyzed that season, 1898, was 13.62 per cent. The average for the season of 1899 was 14.69 per cent.* The effect upon the tonnage of the crop was not determined, but it was not materially affected in any observed case.

This is unlike the effects of a late and inopportune rainfall. The bad effects of this are probably due to the condition of the crop at the time of the rainfall, and not particularly to the amount of water that falls.

Cultivation and manuring increased the amount of phosphoric acid taken up, but did not increase the percentage of ash in the fresh beet. The greatest effect seems to have been on the percentage of chlorin taken up, it having been lowered.

The percentages of phosphoric acid, lime and magnesia in the ashes of the samples of 1897 and 1898 were very nearly the same, but in 1899 the percentages of the two latter substances increased by one per cent. each.

The changes produced tend to bring the composition of the ashes more into harmony with the results of other observers, and indicate the tendency of cultivation and continued cropping to ameliorate the soil conditions and modify their effects upon the mineral matters taken up by the plants.

The effect of the manure was of two characters, mechanical and as a fertilizer.

The nitric acid in the ground waters was more variable and higher after than before the application of the manure.

The total solids were also higher during the season immediately following its application.

Heavy rains or an irrigation increase the amount of chlorin in

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* The average of all varieties, manured and not manured. The average for the not manured sections was 15.34 per cent.

the ground water. The increase was more pronounced and of longer duration after the manure was applied. The effects of the straw upon the soil lead the writer to attribute the effects of the manure principally to the organic matter in it, improving the mechanical condition of the soil and bettering its biological conditions, as indicated by the increased amount of nitric acid formed.

Experiments made in 1897, 1898 and 1899 upon the effect of soaking beets in water at a temperature of about 42 degrees Fahrenheit for a period of seven days, resulted uniformly in showing an increase in the amount of sugar present, and also in the coefficient of purity.

The reducing power of beet pulp was determined by extracting the beets with 80 per cent. alcohol until the extract no longer reacted for sugar, then boiling with dilute hydrochloric acid and determining the reducing sugar thus formed and calculating it as pentose. The pentoses, or, as it is expressed in the bulletin, the reducing power, did not decrease as the beet matured. The rich beets showed higher percentages of pentoses than those showing lower percentages of sugar. The quantity of pentoses in stock beets is quite as great as that in sugar beets.

Soaking seemed to diminish the quantity of pentoses present.

The sugars present in the leaves of sugar beets in largest quantities are glucose and maltose. Cane sugar is present in small quantities only, or is entirely absent.

CONCLUSIONS RELATIVE TO THE CULTURE OF SUGAR BEETS.

A rich, loamy soil is best adapted to the growing of sugar beets, but any soil that will produce good crops of grain will grow beets, and even soils too alkali to grow grains will grow beets.

Plowing is best done in the fall, subsoiling to fifteen or eighteen inches. Plowing may be done in the spring; in this case it is best to plow immediately before planting. In either case harrow quite smooth and even.

Results at this Station show a gain of 18 per cent. in weight of crop, in favor of subsoiling.

The time to plant will vary with locality and soil. Early planting gives largest crops. Good results have been obtained with plantings as late as June 13th at this Station, and June 15th at Rockyford, but four series of tests of ten experiments each, made in different sections of the State, show an average excess of 3.4 tons of beets for the plots planted from April 10th to 20th over similar plots planted from May 1st to 10th; 7.3 tons over those planted May 15th to 26th, and 12.4 tons over those planted between May 31st and June 10th.

If the soil is wet, very shallow planting will give good results, but the best results are generally obtained by planting from one inch to an inch and a half. Deeper planting is not advisable.

The distance between rows should be from 18 to 20 inches if in single rows. Mr. Watrous, in bulletin No. 21, recommends double rows 12 inches apart and 24 inches between rows. He claims that they are more easily irrigated. Prof. Cooke, in bulletin No. 57, recommends double rows 11 inches apart and 27 inches between rows.

Good crops have been raised by planting small quantities, three to five pounds of seed to the acre, but it is advisable to sow eighteen or twenty pounds to the acre. One of the most difficult things in beet growing in Colorado is to get a good stand.

In order to get a satisfactory germination of the seed, one or other of the following methods have given the best results: Either plant on freshly plowed soil with a good supply of moisture, or irrigate up.

Cultivation should begin as soon as the plants show the drills distinctly enough to be easily followed, when the surface should be thoroughly stirred to kill the young weeds. The young beet plants must not be covered.

Thinning may be begun as soon as the plants have gotten big enough, when they have four leaves, and may be extended over a period of two weeks. As the plants get larger, more care must be exercised on the part of the persons thinning, to avoid injury to the remaining plants.

The distance between the beets in the row may vary from six to ten inches —eight inches on an average gives a satisfactory crop. There is but little

difference in the weight of the crop when the beets stand six, eight or ten inches apart. At twelve inches apart the beets are apt to attain an undesirably large size.

The cultivation of the crop must be varied according to the character of the soil. Any instrument, the plow, the cultivator or special beet cultivating implement, which will put the soil in good condition without covering or otherwise injuring the plant, may be used. During the growing season the beets should be cultivated as soon after an irrigation as is practicable, to prevent encrusting of the surface, to level the ground, and to make a mulch of fine earth.

The number of irrigations necessary to raise a good crop will vary with the seasons. Mr. Watrous, in bulletin No. 21, says that in ordinary seasons, with an average rainfall of 13.89 inches, one irrigation during the growing season is sufficient to produce the best results. Some experiments made at Rockyford under Prof. Cooke gave the same result. The rainfall of that season was unusually heavy. If the water is at the command of the grower, the beets should be irrigated often enough to keep them growing continuously from the beginning of the season until the time of harvesting. Under this condition it pays to irrigate until late in the season. The difference in the halves of six plots, one half receiving no water after August 20th and the other receiving two irrigations after this date, was one seventh of the crop, in favor of the later irrigation.

It would be difficult to designate the best variety. The various strains of Kleinwanzlebener and Vilmorin probably take precedence. The Lion Brand, Mangold and Zehringen have given excellent results.

The plots grown under the direction of this Station or on the College Farm have given large yields. The average for ten counties of the State in 1898 is given as 19.9 tons. In 1899 the averages for eight series of twelve plots each ranged from 15.3 tons to 27.7 tons per acre. The writer's experience and observation would lead him to put the average crop for this section of the State at from 10 to 14 tons, ranging from six to thirty tons per acre.

The average percentage of sugar in the beet will probably be not far from 13 per cent., taken for a series of years; the range in the different crops will be between 10 and 20 per cent.

The average coefficient of purity will be between 79 and 81; in very favorable years possibly 82, in unfavorable years 77 or 78.

The date of ripening will vary with time of planting, soil, season and treatment of the crop. The earliest harvesting of workable beets of which I have record for Larimer county is September 15th; sugar 14.71 per cent., purity 80.4.

Our experience with transplanting beets is that the beets produced are of very ill shape, but may be rich in sugar, and yield well.

The application of a liberal dressing of well rotted manure will lower the percentage of sugar and coefficient of purity a little, but the crop will be increased more than enough to compensate for this.

Beets should not be permitted to dry out after being dug, as there is a loss of sugar.

Freezing does not destroy the sugar in beets, but freezing and thawing injures the beets for sugar making.

The beet is a vigorous feeder. A crop of 14 tons of beets would remove 300 pounds of mineral matter, about one half of which, or 150 pounds, is potash, and 25 pounds is phosphoric acid. If the tops are taken off the field there will be a still larger quantity of these substances removed. The fertility of the soil may be maintained by the application of well rotted manure, and by a judicious rotation of crops.

The trimmings of the beets make good fodder for cattle. The fresh tops, however, are apt to have a laxative effect.

The dry matter in the beet pulp is of rather more value, pound for pound, than the dry matter from the fresh beet. The pulp as obtained from the silo contains 90 to 92 per cent. of water. Slight fermentation is said to improve it.

We have grown beets carrying as high as 19 per cent. of sugar in soil rich in "alkali" salts. The average percentages of sugar for the crops of 1898 and 1899, grown in such soil, were 13.65 and 15.34 respectively. The coefficients of purity were 84.6 and 80.8.

As a rule medium sized beets are richer than either small or large beets. By medium sized beets is meant such as weigh from one to two pounds. Large beets, beets weighing from two to four or even many more pounds, may be as rich in sugar and have as high a coefficient of purity as beets of one pound or less, if grown under the same conditions. If not grown under the same conditions they cannot be compared. Even big beets grown under different conditions cannot be compared. Two beets, weighing respectively 2.88 and 2.90 pounds, grown in the same plot of ground within two hundred feet of one another, but under different conditions in regard to water supply, showed 10.45 per cent. sugar, 67.0 per cent. purity, and 16.06 per cent. sugar and 85.1 purity. Big beets *may be* rich beets, the size alone is not determinative.

It has been stated that one irrigation may, under certain seasonal conditions, suffice to produce the best results in regard to crop and quality of beets. Under other conditions of the season or soil, or both, more irrigations will be necessary. The condition of the crop will determine how late in the season irrigation may be profitably practiced. If the crop has already begun to ripen either a rainfall or an irrigation which causes a second growth will prove detrimental, but if the crop is in such condition that a second growth is not produced a late irrigation may do good.

A late over-irrigation ofter does good, hastening the ripening and increasing the sugar. It has not been determined that it will uniformly produce this result. The character of the soil will probably modify the effect.

The higher parks of the State are not adapted to this culture, but good crops of rich beets have been grown in the San Luis valley at an altitude of rather more than seventy-five hundred feet.

The beet growing almost wholly under ground in this State, the loss in trimming is reduced to a minimum. Experiments indicate about 13 per cent. loss.

The amount of sugar in the crown of the beet, as it grows with us, is about one per cent. less than there is in the beet.

The cost of growing and harvesting an acre of beets will, of course, vary, but it is not far from thirty dollars per acre, exclusive of ground rent.

The growing of this crop will be more successful and the cost often materially lessened by the exercise of good judgment on the part of the cultivator. Specific rules for its culture, applicable to every case, cannot be laid down, and it must furthermore be remembered that even the very best rule can be so indifferently carried out that it may produce very poor results. No amount of experimentation can eliminate the difference between an intelligent, observing cultivator and one lacking these characteristics. Some land needs to be treated in a manner which would be wholly inapplicable in another case. Men who have tilled and irrigated their farm lands for years have learned how to treat each separate part of their farms. This knowledge is probably the secret of their success. No general statement regarding the culture of beets can be properly interpreted without taking these special facts into consideration.

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BULLETIN No. 1, SEPTEMBER, 1899.

THE SUGAR-BEET CATERPILLAR.

BY CLARENCE P. GILLETTE.

The horde of caterpillars that have been devastating the beet fields during the past two weeks, between Palisade and Grand Junction, and that have occurred in small numbers from Grand Junction west towards Fruita, require the prompt attention of all interested in the success of the sugar beet culture in the Grand Valley, that the loss to this year's crop may be quickly checked and that severe losses for the coming year may be averted.

During the early part of the week (August 14th to 16th) the writer visited many beet fields in company with Mr. C. E. Mitchell and others, for the purpose of determining the nature and extent of the injuries, the length of time the attack is likely to continue, what remedies it will be best to apply, and other points of importance concerning the caterpillar.

The insect was found in the fields in all stages of development, except the egg. The caterpillars varied in size from those that did not exceed a sixteenth of an inch to the fully grown individuals that measured from an inch to an inch and a fourth in length. A large proportion were half grown or more, and many had changed already to the chrysalis or pupa state, just beneath the surface of the ground.

The fact that there are still many small worms makes it certain that the attack will continue to some extent to near the end of the present month (August). A quantity of the chrysalids were placed in suitable receptacles, and from them several moths, which are the adult insect, have appeared at this writing. The females are found to be heavily laden with immature eggs, and it is highly probable that within a few days these eggs will be deposited on or about the beets for a succeeding brood of worms. It is greatly to be hoped that the moths now hatching are only belated individuals of the second brood and that another full brood will not appear this summer. However this may be, not a day should be lost in beginning the work of destroying the

caterpillars now upon the beets. If the present brood is allowed to mature, it means a greatly increased number of caterpillars to contend with next year. It is with insects as with plants. The greater the number allowed to mature this year, the greater will be the quantity of seeds sown, and the larger will be next year's crop. The old adage, "A stitch in time saves nine," is more than doubly true when dealing with the destruction of insect life.

The closest watch should be kept during the next two or three weeks for the appearance of small worms. If none seem to be present, look carefully among the small and tender leaves at the base of the large ones, where they may be found.

REMEDIES.

A moderate number of friendly insects were found about the beets. These were lady-beetles, Aphis-lions and ground-beetles, all of which were probably preying to some extent upon the small caterpillars. Birds were very scarce in the beet fields; the crow seemed to be doing more than any others of the feathered tribe to destroy the caterpillars. It is plainly evident that the natural enemies are far too few to be of much service at present in keeping this insect within proper bounds. Artificial measures must be adopted to save a good partial crop of sugar beets over the eastern portion of the plantations about Grand Junction this year, and without these measures the crop over the whole valley may be largely a failure another year.

The caterpillars can be destroyed. The writer used both Paris green and kerosene emulsion, with satisfactory results, while at Grand Junction. The emulsion is more expensive and needs to be applied very thoroughly to give good results. The caterpillars should be thoroughly wet with it. This remedy would be specially useful on those fields where the caterpillars are very abundant and of large size and where the tops of the beets have been nearly or quite devoured. The chief benefit from destroying these caterpillars will be to lessen the number of the next brood.

By closely watching for the first appearance of the caterpillars when they are small, and then promptly and thoroughly treating the beets with Paris green or other arsenical poison, it is believed that the pest can be quite easily kept in check.

The poisons may be applied in a watery spray in the proportion of a pound of poison to 100 gallons of water.

Apply with force in a fine spray, and be thorough, but do not continue the spray in one place until the drops run together and carry the poison with them off the leaves. Where small patches are to be treated, a very simple method is to mix one pound of Paris green with about 20 pounds of common flour, and apply by dusting the mixture over the plants. This is readily done by placing a quantity of the poisoned flour in a small cheese cloth sack, which is held in the hand and shaken over the plants as the operator walks down the row of beets. This application can be best made when there is no wind and when there is a dew or rain upon the leaves to make the poison and flour stick.

No. 2, APRIL, 1900.

COLORADO SUNSHINE.

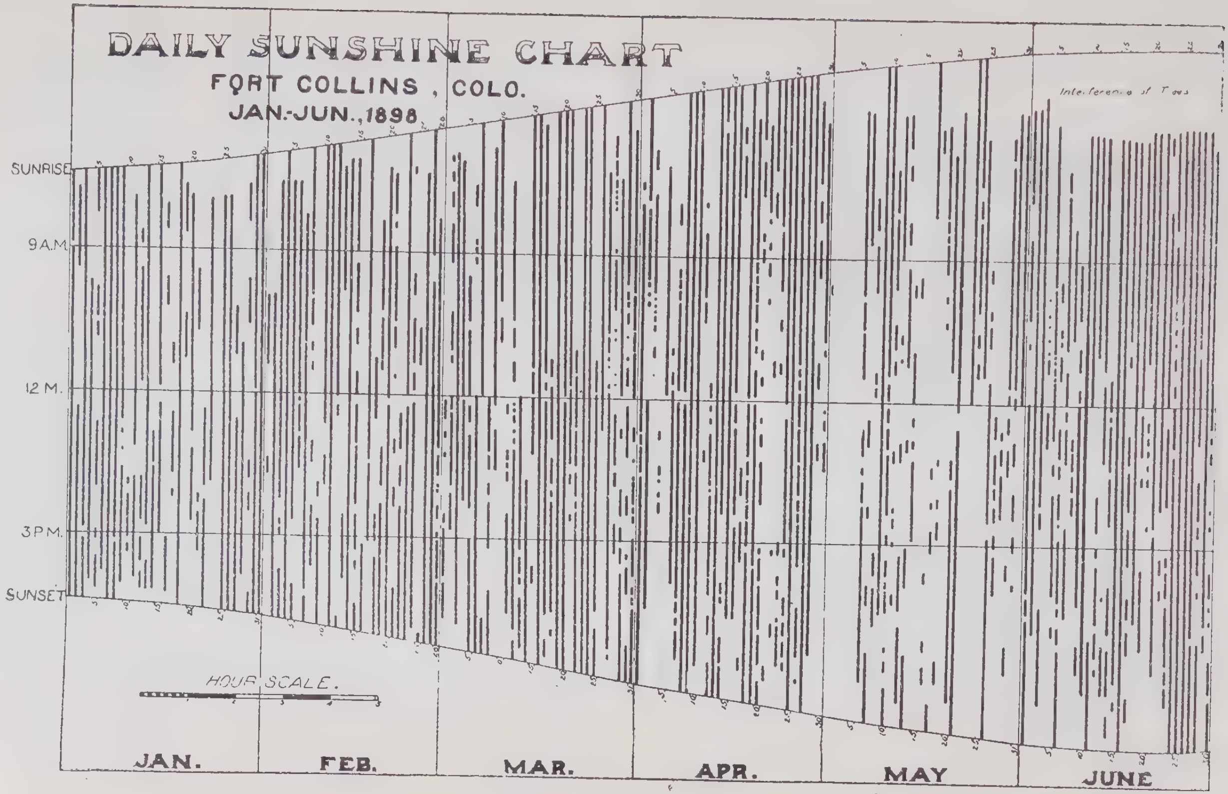
BY L. G. CARPENTER.

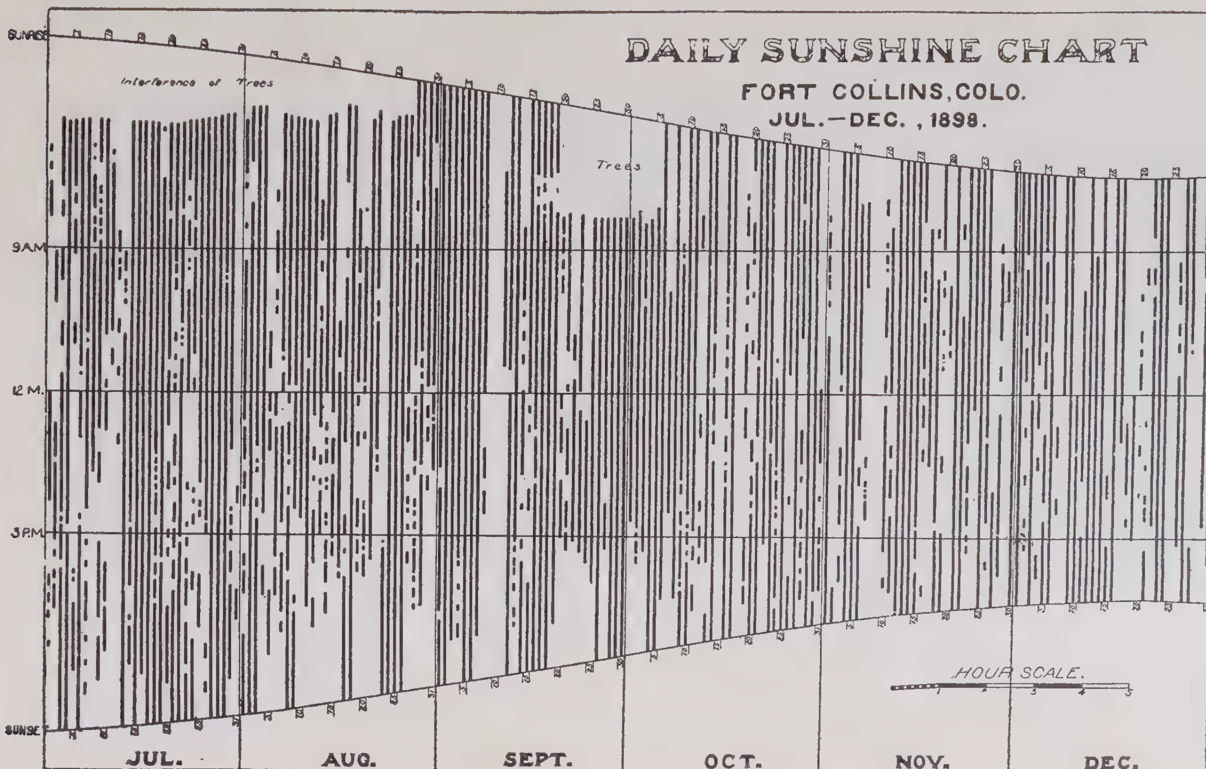
The important effect of sunshine on plants, their growth and development, their aromatic oils, the color of their flowers, and the quality and color of their fruit, is well known. That it has an equal influence on the spirits and health of man, is also well recognized. In general it has a beneficial influence on useful plants, while destructive to injurious ones, as molds, fungi, and bacteria. It is one of the most potent germicides. Most diseases cannot spread in the presence of sunshine.

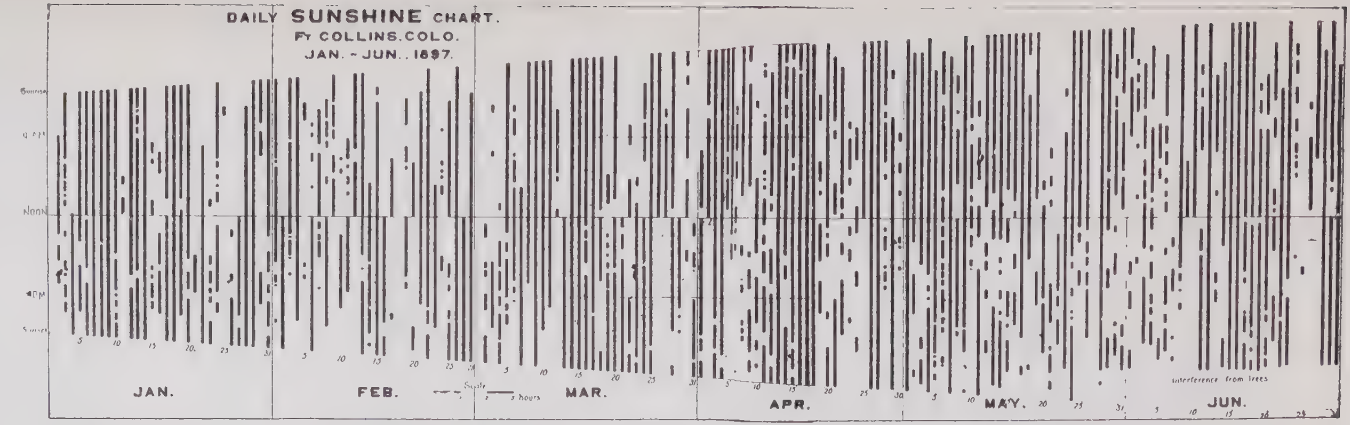
The following charts showing the sunshine day by day, throughout two years, are of more than passing interest, both from an agricultural and a sanitary standpoint. The record is made continuously at the Experiment Station.

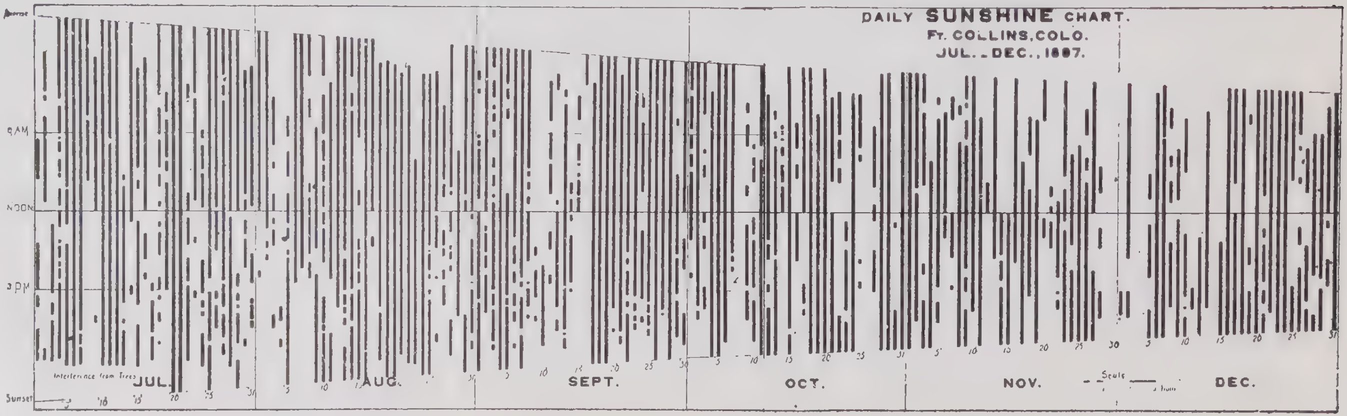
The full lines show the sunshine. The breaks in the lines show when the sunshine was interrupted by clouds passing over the sun. The diagrams show at just what hours the sun shone on each day of these two years. Attention is called to the few days without some sunshine. May was the rainy month in 1898.

The record for 1897 is on one-half the scale of that of 1898.


DAILY SUNSHINE CHART
FORT COLLINS, COLO.
JAN.-JUN., 1898
SUNRISE
9 A.M.
12 M.
3 P.M.
SUNSET
HOUR SCALE.
JAN.
FEB.
MAR.
APR.
MAY
JUNE


DAILY SUNSHINE CHART
FORT COLLINS, COLO.
JUL.—DEC., 1898.
Interference of Trees
Trees
SUNRISE
9 AM
12 M.
3 P.M.
SUNSET
JUL.
AUG.
SEPT.
OCT.
NOV.
DEC.
HOUR SCALE.


DAILY SUNSHINE CHART.
Ft COLLINS.COLO.
JAN. - JUN.. 1897.
Sunrise
NOON
Sunset
JAN.
FEB.
MAR.
APR.
MAY.
JUN.
Scale
3 hours
interference from trees


DAILY SUNSHINE CHART.
Ft. COLLINS,COLO.
JUL. - DEC., 1897.
9 AM
NOON
3 PM
Sunset
Interference from Trees
JUL.
AUG.
SEPT.
OCT.
NOV.
DEC.
Scale

No. 3, MAY, 1900.

THE BEET ARMY-WORM.

BY CLARENCE P. GILLETTE.

The caterpillar which did so much injury to sugar beets in the vicinity of Grand Junction last year will doubtless appear again this summer. While the insect has long been known to entomologists, last year was the first that it has ever been reported doing serious harm to any crop.

While the life habits of the insect have never been studied, it seems probable, from what the writer could learn of it last summer and fall, that it has two broods in the course of a year. The caterpillars that were so abundant during August last year entered the ground and then appeared again as moths in September. There were few enemies to destroy the caterpillars and the moths hatched in enormous numbers. These moths, like house-flies and mosquitos, seek every available place of protection from winter's storm and cold that they may live (hibernate) until spring. When vegetation starts the moths, laden with eggs, go in search of beets or other plants furnishing suitable food, to deposit their eggs and thus provide for an early brood of worms. If ten per cent. of the fall brood of moths survived the winter, there is serious danger that beets will fare worse this summer than they did last, unless growers are early on their guard to make thorough and timely application of effectual remedies. Just here let me warn all against experimenting with new or patent remedies which some friend or vendor may think entirely satisfactory. Use such remedies very cautiously and sparingly at first, or do not use them at all.

From what could be gathered last summer, it seems that there was a first brood of caterpillars at about the time for thinning the beets, which, in some cases, destroyed most of the plants after thinning.

REMEDIES.

Experiments tried last summer proved that the common poisons, Paris green, London purple, and white arsenic, will destroy the caterpillars if well distributed upon the beets. These poisons may be applied dry or in water. If the caterpillars appear upon the beets while the

latter are small, I believe the best method of application is to mix one part by weight of Paris green or London purple with twenty parts of common flour, and then dust the mixture over the plants before sunrise in the morning. In this strength a light dusting will be sufficient. The early application is recommended, because the leaves have then a slight amount of moisture upon them, which helps to hold the flour and poison. Just after the leaves are moistened by a shower is also a good time to make the application.

To apply the poison, make a small cheesecloth sack about five inches in diameter and ten inches deep. Fill it with the mixture of poison and flour and walk along a row of plants shaking the sack over them. This can be done quite rapidly when one has learned how, is economical of poison, and does not require wheelbarrow or wagon to carry pump and tank.

When the plants become large, as in case of treatment for the second brood, it will probably be better to use a barrel or tank and spray pump.

If a spray is used, apply either Paris green or London purple in the proportion of a pound to 100 gallons of water and add two pounds of fresh lime for each pound of poison. The lime should be slaked and strained through a cloth to take out lumps. Then use a nozzle that throws a fine spray, and do not continue the application in any place long enough so that the drops sprayed upon the leaves will run together and flow off, carring the poison with them.

If white arsenic is used, prepare according to the following directions:

Put two pounds of white arsenic and eight pounds of sal soda together in a dish and boil for twenty minutes in two gallons of water, and keep as a concentrated solution. *It is extremely posionous and should be placed at once where there is no possibility that children or domestic animals can get it. Also, label it "poison" in large letters.*

Then, in each 40 gallons of water, first slake four pounds of lime and then add slowly one quart of the concentrated solution while the whole is being stirred. The mixture is then ready for application, as in the case of Paris green. The lime should be strained through a cloth to take out the lumps.

I am advising the use of these poisons somewhat stronger than is common, but the experience of last year makes it seem advisable to do so.

Growers should keep the closest watch of their beets this year, in order not to let the caterpillars get the start of them. I hope to be notified of any appearance of these worms or other injurious insects promptly, and shall be glad to do all in my power to aid those who are anxious to save their crops from the attacks of such pests.

No. 4, JUNE, 1900.

THE CANTALOUPE BLIGHT.

BY H. H. GRIFFIN,

Rocky Ford, Colorado, has long been famous for its cantaloupes. Until of late the industry has moved along at a rapid pace, little disturbed by insects or plant diseases. The blight, or rust, was first noticed on a few patches in 1896. There was an increase of the disease in 1897, more especially on the same fields, but its spread was not suffient to cause much alarm. There was a vast extension of the disease in 1899 and the severity was much greater. The disease seemed to spread from a few well defined centres and grew less with distance from these centres. Many points in the Arkansas Valley report no injury. All evidence shows that the disease is not caused by any particular soil conditions, mode of irrigation, or peculiarity of climate.

The station began to investigate the question in 1898. Prof. Crandall, in 1899, pronounced the trouble due to a fungus, a new species named by Ellis and Everhart "*Macrosporium cucumerium*."

Seed taken from diseased melons was planted in 1899 to see if the disease was communicated by the seed. Three rows, each 250 feet long, were planted May 12th. The middle row was sprayed with Bordeaux mixture to test its efficacy as a preventative, or, should the disease appear, for its control. Sprayings were given to the middle row June 22nd, June 30th, July 22nd, July 31st and August 11th. At the time of the first spraying there was no appearance of the blight, but at the time of the second spraying it was noted that "something on the leaves that looked like blight" had appeared. Previous to the 19th of June the weather had been very dry, so that if any infection had been present it is not probable that its spread would have been rapid enough to become apparent. After this moisture was plentiful; seven inches of rain fell in July; 5.14 inches in the week commencing July 14th. These rains submerged the vines and could not fail to wash off the spray. At the third spraying the blight was strongly in evidence. In August 2.22 inches of rain fell and dews were prevalent. A decided benefit was derived from the sprayings made after the 22nd of July. The sprayed vines held up comparatively well, and

the fruit was of good quality. On the unsprayed vines the fruit ripened prematurely; they were insipid in taste, and it could be detected from which vines they were picked. The sprayed vines remained green and in a growing condition for two or three weeks after the others had succumbed. The plants grown from diseased seed did not seem to be more susceptible than those grown from seed from healthy vines.

Other experiments were inaugurated in the latter part of July on a more extensive scale. Both the Bordeaux mixture and an ammoniacal copper carbonate solution were used on different vines at each place. The first spraying with the Bordeaux mixture was given July 27th and the last August 18th. The carbonate was first used August 4th and and the last spraying was made August 18th.

The test was made on seven rows, each 275 feet long, the vines that were sprayed remaining in good condition fully ten days after the others were gone. The melons ripened slower, in better condition, and were of uniformly good quality.

The results from the carbonate were not so pronounced as from the Bordeaux mixture. The results from the above work were so promising that it was tested on a still more extensive scale. About ⅛ of an acre of melons belonging to Senator Swink were sprayed. About one acre was sprayed for Mr. John Deweese, and one and three-fourth acres for Mr. C. S. Fenlason. Only one application was made at these places. These sprayings were done late in the season, when the blight was spreading rapidly. These melons were surrounded by others that were blighting badly.

The work confirmed the result of the other trials. Mr. Fenlason sold 300 crates of good melons from his sprayed field.

The virtue of the spraying lies largely in the ability of the melons to ripen properly, *i. e.*, to perfect the quality; the benefit is not alone to the vine.

It took 22 pounds of bluestone to spray the vines at Mr. Fenlason's, which were very large. The estimated cost was $6.75 per acre. Had the work been done earlier the cost would have been much less.

APPEARANCE OF THE DISEASE.

The cantaloupe blight is caused by a true parasitic fungus. To the casual observer the first appearance is a large number of small brown spots upon the leaves in the

center of the hill. If the younger leaves are examined, it will be seen when the fungus is at work some time before the brown spots make their appearance. It can be seen when the leaf tissue has been eaten away, and when the injured tissue dies the brown appearance occurs. These brown spots grow larger as the fungus kills the tissue, until they become so numerous as to envelop the whole leaf; it appears as though struck by frost. It is surprising how quickly the spray will prevent the enlargement of these spots upon the leaf. At the time spraying is required the melon vine is making quite rapid growth, which necessitates spraying at intervals in order to cover the new growths.

HOW THE ACTION IS PERFORMED.

It can be readily seen that if some material is put upon the leaves that will kill the fungus, without injuring the host plant, the desired action is performed.

No fear need be felt that the bees will be poisoned. A number of hives stood near one of the fields treated, but no dead bees were found nor could it be seen that any injury resulted to them.

From the work of this season, we can advise that two or three spraying be given should the weather conditions prove favorable for the spread of the disease. If a dry season occurs perhaps the disease will not develop to any injurious extent.

From our present knowledge we should say that the first spraying should be done about the middle of July, followed every ten days until two or more are given, depending upon the weather. It would be well to follow the first rains of July with a spray.

Directions for making Bordeaux Mixture for use upon cantaloupes:

Dissolve 6 lbs of bluestone.
Slack 4 lbs. of fresh lime.

When the lime has become cool strain off the milk, adding it to the bluestone. Add water until there are 40 gallons.

No. 5, JULY, 1900.

THE RUSSIAN THISTLE AS FORAGE.

BY J. E. PAYNE,

In many localities, the Russian thistle threatens to take possession of the land, in spite of all efforts of public-spirited people to keep it in check.

In neighborhoods where it has taken possession of the land, it seems best to ask—Can it be used for the benefit of the people whose land it has invaded?

The value of the Russian thistle has never been tested by a feeding experiment at any Experiment Station so far as we know, but the Minnesota Station has analysed the plants in various stages of growth. The following, copied from the Experiment Station Record, page 553, Vol. 6, gives the substance of Bulletin No. 34 of the Minnesota Experiment Station:

"When young the thistle is claimed to have a high food value, especially for sheep, which, some claim, are attracted to it merely on account of the salt which it contains. The chemical analysis shows a large percentage of ash material, amounting to nearly one-fifth of the dry weight of the plant. This is a serious objection to its use as a fodder plant, on account of the alkaline nature of the mineral matter present. One favorable point, as shown by analysis, is the large amount of nitrogenous matter present, being as much as there is in clover or rape. Before the development of the thorns, there is not much fibre present; at this time the plant is more valuable as a food than when mature. When the plant is ripe, the fibre and mineral matter make up half its composition, and although rich in nitrogenous matter, the former elements greatly reduce its feeding value

"The ash analysis shows that the weed has strong foraging powers, there being large amounts of potash and lime taken up by the plant. The draft which the plant makes upon the sodium in the soil is a benefit to alkali lands. The amount of sodium present varies greatly with conditions, showing that the plant is able to adapt itself to the alkaline conditions of the soil. From the time the thorns are out until the plant matures it takes up a large amount of sodium from the soil, and only small amounts of other materials, hence it makes the heaviest draft upon its soil while in an immature state, after which it takes but little essential plant food."

The following testimony concerning the use of Russian thistles as a food for stock has been gathered from men who have had more or less experience in feeding it:

"Cattle eat Russian thistles, but they are poor feed."

CHAS. HACKENBERGER,
Burlington, Colo.

"Cattle will eat Russian thistles in large quantities. They physic cattle."

THOMAS SEAMAN,
Wallet, Colo.

"Cattle eat Russian thistles. They seem to do well on them."

ELMER BROWN,
Wallet, Colo.

"I am feeding my bulls, which I keep up, Russian thistle hay. Consider it good feed when cut before the thorns harden."

SAMUEL P. SHAW,
Lamborn, Kansas.

"During the winter of 1899-1900, I fed a part of my cattle millet, and the remainder, about 40 head, Russian thistle hay. Those fed Russian thistles wintered fully as well as those fed millet Fed none except during storms. Fed Russian thistles to those that were the best rustlers"

LEO THOMAN,
Burlington, Colo.

"In June, 1895, my cows fed on young Russian thistles. I never made better butter nor more of it than I did that month."

A. C. WILLS,
Lamborn, Kansas.

"My sheep eat Russian thistles, both green and dry. I think a patch of Russian thistles worth as much, for sheep feed, as the same area in grass."

WM. LANG,
Cheyenne Wells, Colo.

"When I first began farming here, when wheat failed I had no feed for stock. Now, when wheat fails, Russian thistles take posession of the ground. I cut these and winter my cattle on them."

JOSEPH RUBY,
Thurman, Colo.

The investigation has not been carried far enough to warrant us in recommending the Russian thistle as a hay plant when there is plenty of other forage. But the above testimony convinces us that those whose land is occupied by the thistles should cut some and try them as a feed for stock.

No. 6, DECEMBER, 1900.

A SO-CALLED BLIGHT CURE.

BY CARL H. POTTER,

The "Woodbury Blight Cure" as its name implies, is a proprietary article that has recently been placed on the market. This "cure" is guaranteed to be a certain remedy for the blight of apple and pear trees if used as directed, and a destroyer of insect pests as well. Two mixtures are sold by the company controlling the cure, a body wash and a summer spray. The claims for the remedies and the directions for their use, as set forth by the company, are as follows: *

"The body wash should be used at least once during the season, preferably early in the spring on account of sun scald, but of immense benefit any time in the year.

"The summer spray should be used at least three times during the season for the cure of the blight and the destruction of insect pests. It should be used after, or during, every severe electrical storm for an insurance against the twig blight.

"Spray the first time when the trees begin to leaf, again from the middle to the last of July. Follow these directions carefully, and we will guarantee a cure for blight and the practical destruction of the codling moth and other injurious insects. The spray is beneficial and will promote a strong, healthy growth in all plant life, more especially on roses and vines. It will destroy slugs and green flies in the green-house."

On account of the fact that a large sale of such cure had been made, and that many inquiries had come to the Station, it seemed proper for a trial to be made.

June 29, 1898, a number of bearing apple trees in the Station orchards were selected and prepared for trial. Four distinct series or lots of trees were treated, while the others, as similar as it was possible to select them, were wholly untreated. These entered the test merely as checks with which to compare the trees that were treated. All of the trees to which the remedies were applied were recorded as class "A," while the untreated, or check trees, were class "C."

The different series of trees comprised summer, fall, and winter apples, and varied from very slight affection of the twigs to quite severe cases of blight, in which many of the smaller limbs were entirely diseased, the blight even forming large and more or less concentric patches on the

* From printed directions provided by the company.

larger limbs about the bases of the smaller ones. The trunks were not very badly affected by blight, yet there was plenty present for a test. Those trunks that were rough, whether in class "A" or class "C," were thoroughly scraped before treatment.

On the afternoon of June 29th the trunks and the lower portions of the limbs, to a height of about four feet from the ground, of the trees of class "A" were treated to an application of Woodbury's "wash," the material being applied with a stiff paint brush. About one quart of the mixture was used for each tree.

The following afternoon, June 30th, the same trees were thoroughly sprayed with the "spray mixture." The mixture was used double strength, as the directions recommended where an early spraying had not been given. The material was thoroughly stirred and then diluted to the strength of $\frac{4}{5}$ of a quart of "wash" to $4\frac{4}{5}$ gallons of water. Five gallons of this diluted mixture were used on each tree, the services of one man being constantly required to agitate the liquid in the box of the spraying pump. Blighted parts received especial attention.

August 13th all of the trees in class "A" were sprayed as before, except that the spray or "cure" was used as diluted in the proportion of one part of spray to 49 parts of water. November 15th the trunks of all the trees in class "A" were washed as before.

April 18, 1899, the trunks were again painted with the wash, a very thorough job being done. The trees were entirely dormant.

April 21st. Trees sprayed as per directions. Still dormant.

July 19th. Trees again sprayed as per directions.

This completed the application of the remedies to the trees. They had been used nearly two seasons, and were carefully and conscentiously applied. Frequent and careful observations of the trees were made, not only during the two seasons named, but extending through the season just closed. *We have not been able to detect, in any way, the slightest benefit to the trees as result of the use of these materials.*

Concerning the value of the spray as an insecticide, Prof. Gillette makes the following statement:

"I have tested the 'Woodbury Blight Cure,' summer spray, upon both leaf-eating and sap-sucking insects, and in no case did it seem to have any injurious effect upon the insects treated Leaves thoroughly wet with the solution were eaten by insects which afterward matured in perfect condition."

No. 7, FEBRUARY, 1901.

THE SEEPAGE MEASUREMENTS OF THE EXPERIMENT STATION.

BY L. G. CARPENTER.

One of the effects due to irrigation that is noticed in all countries is the seepage water which returns from irrigation and enters the streams. This is so much that streams may be drained dry and, within a short distance, again have an appreciable quantity of water.

At the suggestion of Hon. B. S. LaGrange, President of The State Board of Agriculture, and at that time Water Commissioner of District No. 3, a measurement was made in 1885 of the Poudre River by the State Engineer's office, and two others were made in 1889 and 1890. In 1891 the Experiment Station took up the matter to investigate in detail the amount and the laws of the increase. Such measurements have since been carried on annually on the whole length of streams in the State, from their exit from the mountains to the State line. These include the Cache a la Poudre, the South Platte, the Big and Little Thompson, the St. Vrain and Left Hand creeks, Boulder and South Boulder, Clear Creek, Bear Creek, the Arkansas from the mountains above Canon City to the Kansas State line, the Rio Grande from near Creede to the New Mexico line, and the Conejos. Of these, measurements have have been made for four years on the Arkansas and for five years on the Rio Grande, and the others for varying times.

It has been the intention to extend these measurements to other parts of the State as soon as time and means permitted. During the past year, 1900, the measurements were begun on the Western Slope, and were made on the Uncompahgre River from Ouray to Delta. These measurements have required every foot of the streams to be passed over, every headgate visited, every stream that leaves the river, as well as those which flow into it, to be measured. This has required the traveling over, in detail, of very nearly one thousand miles of river during the past season, and from six to eight hundred miles for each of the past four years. In all, some five thousand miles, at least, of river measurements have been made.

A report, giving the results of investigations up to that date, was issued in Bulletin 33. This discussed the relation of the seepage to the area irrigated and to the amount of water applied, as well as the rapidity of the flow of the waters under ground, and showed that the value of this source of water supply amounted to several hundreds of thousands of dollars. This bulletin has been very widely quoted. The more recent measurements have been given in the annual reports of the Experiment Station, and in the report of the State Engineer. Bulletins discussing these measurements, and comparing them, will soon be issued by the Experiment Station.

In addition to these measurements the Experiment Station has also made hundreds of miles of measurements on canals to determine the amount of loss by seepage from canals, the means of preventing the seepage, and the means of protecting lands from such damage. It is studying the character of the water used in irrigation, the amount of water used in irrigation, and other phases of the irrigation question.

No. 8, APRIL, 1901.

POTATO FAILURES.

BY W. PADDOCK AND F. M. ROLFS.

The Experiment Station has received a number of inquiries from potato growers in various sections of the State in regard to the failure of the potato crop in certain seasons. These failures seem difficult to explain, since there is little blight in evidence, and they occur with experienced growers as well as with beginners, and on soil that would seem to be in a good state of fertility. In some instances the vines are said to have made a luxuriant growth and remained green until late in the season, but when digging time came the tubers were found to be much under size. In other instances a large growth of vines were found to have set an abnormal number of tubers which failed to develop.

At first thought it would seem that some of the elements necessary to the growth of the potato plants were lacking in the soil, and this may be true in some instances, but it will not explain all the failures. Certain fungi or plant diseases have been found to be abundant on the potatoes in various parts of the State, which may have something to do in producing these conditions. One of these diseases has been known in America as a potato disease * less than a year, though it has undoubtedly been present in our potato field for a long time. In Europe it is considered to be one of the most destructive potato diseases. The fungus does not confine its attacks to potatoes alone, but is found in a great variety of plants, including alfalfa, clover and sugar beets.

The disease attacks the potato plant just below ground, cutting off free communication between foliage and tubers. In extreme cases the plants may be killed, and much of the so-called late blight or early ripening of the vines may be due to this disease.

The fungus lives over winter on the stems and tubers of the potato, and on various other plants. The fungus adheres to the tubers in the form of dark patches which resemble bits of soil, and which vary in size from that of a mere speck

* Dugger and Stewart, Bulletin 186, p. 17, N. Y. State Experiment Station, and Bulletin 186, p. 63, N. Y. Cornell Experiment Station.

to areas a half inch or more in diameter. The fungus does not injure the potatoes directly, but it detracts from the appearance of the tubers when offered for sale. But the important point is, that when infected potatoes are planted the fungus is planted with them, and thus the disease is propagated year after year.

The fact that the fungus attacks the roots of alfalfa complicates the treatment, since alfalfa is commonly used in the rotation of crops. If potatoes free from the disease are planted on land which has been in alfalfa within two years, the chances are that the crop will be affected, providing there has been any of the fungus on the alfalfa plants. The length of time that the fungus will live in the soil is not known. German authorities state that it will persist for at least three years. Neither has the kind of crop which should be grown on infected land to starve the fungus been definitely determined; however, it is not known to attack our common cereal crops.

It is too early to recommend a line of treatment to overcome the above conditions, since the cause of the trouble is not positively known, but potato growers who have been troubled in this way may find it profitable to take certain sanitary precautions. Such measures consist in planting potatoes, on land on which potatoes, beets, alfalfa or clover have not been grown for at least three years, and potatoes that are free from disease should be used for planting. If there is reason to suspect that the seed potatoes are infected with fungi, they may be treated with corrosive sublimate or formaline, as is recommended for potato scab.

Formulæ for Treating Diseased Seed Potatoes. *

Corrosive sublimate.............1 ounce
Water........................8 gallons

Dissolve the corrosive sublimate in one gallon of hot water, then dilute with seven gallons of water. Allow the potatoes to soak one and one-half hours. When dry they may be cut and planted, though it has been found to be a good practice to treat the potatoes a week or more before planting, since the treatment may retard germination if done just before planting.

Corrosive sublimate is a deadly poison, and it should be used in wooden or earthen vessels, since it corrodes metals.

Formaline......................8 ounces
Water.........................15 gallons

Soak the potatoes two hours in this solution, preferably but a short time before planting. This solution is somewhat more expensive than the corrosive sublimate treatment but has the advantage of being non-poisonous, and it may be used in any kind of a vessel.

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* Jones, L. R., and Edson, A. W., Vt. Sta. Bul., 85.

No. 9. APRIL, 1901.

SUNSHINE FOR 1900.

BY L. G. CARPENTER.

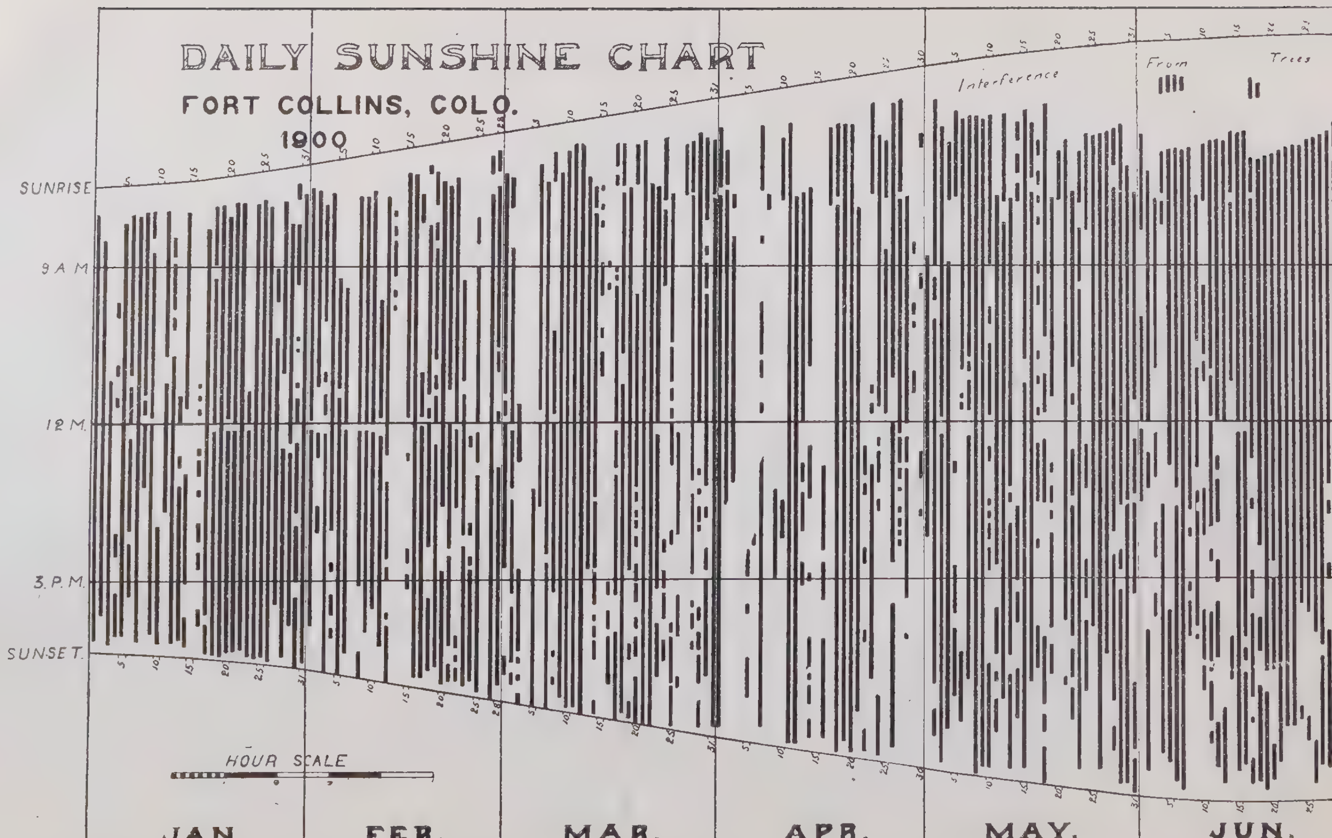
While the pleasure afforded by a sunny day is of common experience, the value of sunshine as an element in the climate, whether from the standpoint of health or spirits or of agriculture, is not often given the importance it deserves. Until recently no attempt has been made to record the amount or intensity, even in those places specially interested in agricultural meteorology.

A certain amount of sunlight is recognized as a necessity for plant growth, for without it the development will be absent or unhealthy. With an increase in sunlight there is almost always an improvement in quality, and in the amount of essential oils; or in special qualities, as in sweetness, and an increase in the color of fruits and flowers. There is a decrease in the prevalence of certain diseases with direct sunshine. It has been known from time immemorial that dirt and darkness were conditions favorable for disease, while cleanliness and light were unfavorable. Molds and fungi, and the invisible but perhaps more important bacteria, do not thrive in sunshine. Even in diffused light few bacteria develop, and direct sunshine is destructive to most, if not to all, injurious forms within a short time. Sunshine and the drying action of the air are unfavorable to such forms of life, and are Nature's chief disinfectants.

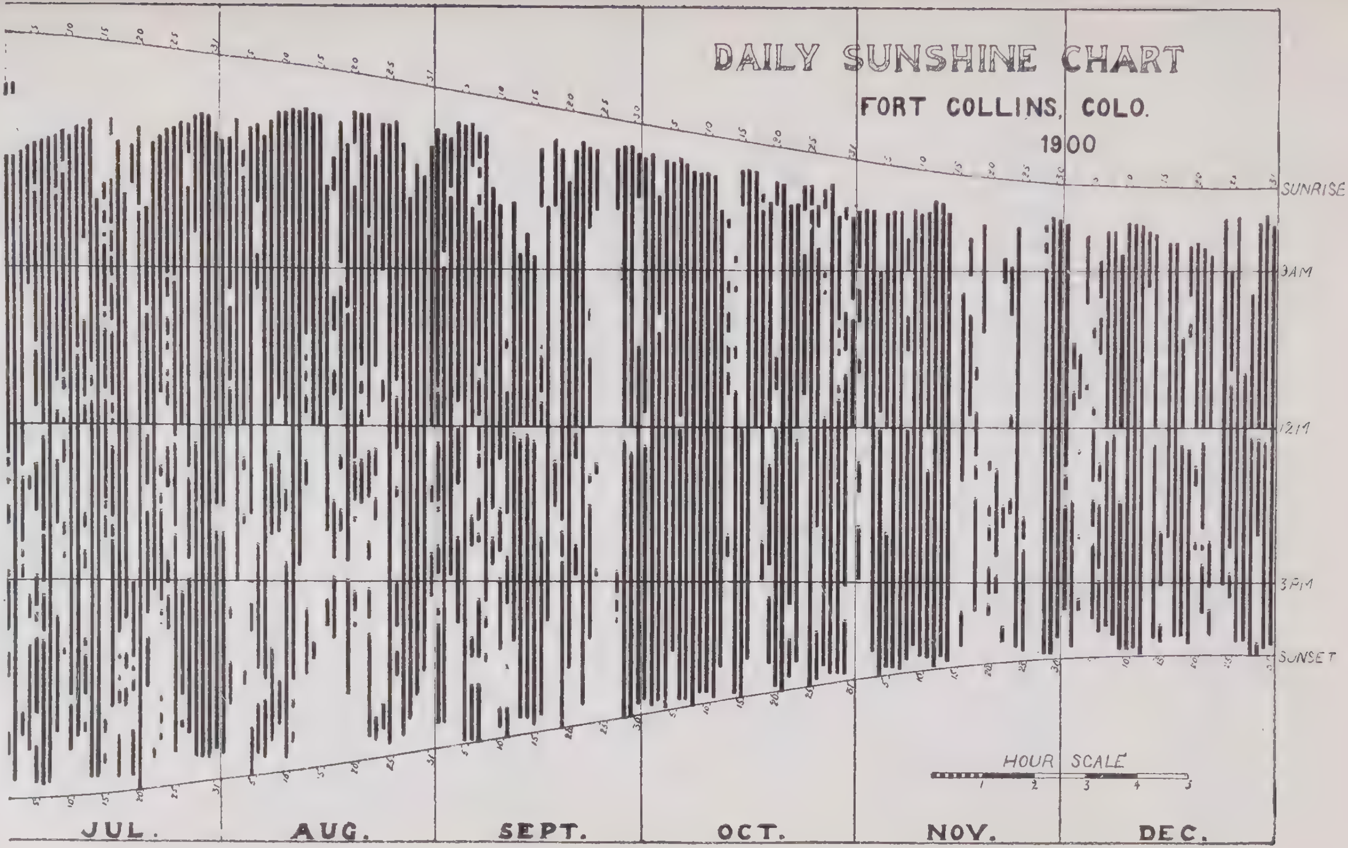
A sunny climate or a sunny home is thus more apt to give the conditions for such physical health as are necessary to permit of sunny dispositions.

The charts show the amount of sunshine at Fort Collins for 1900, as recorded by an automatic photographic recorder and then transferred to the diagram.

A line is given to each day. The black line shows the duration of the sunshine and the hours at which it shone. When broken or absent, clouds are indicated. The longer the break, the longer the duration of the cloudiness. The diagram therefore shows the exact hours at which the sun shone during the year. It is noticeable that the forenoon had more sunshine than the afternoon, and that the winter months had comparatively little cloudiness. The relative amounts vary in different seasons, as a comparison with the charts in Press Bulletin No. 2 of 1900 will show.



DAILY SUNSHINE CHART
FORT COLLINS, COLO.
1900
SUNRISE
9 A M
12 M.
3. P. M.
SUNSET.
Interference
From
Trees
HOUR SCALE
JAN.
FEB.
MAR.
APR.
MAY.
JUN.


DAILY SUNSHINE CHART
FORT COLLINS, COLO.
1900
SUNRISE
9AM
12M
3PM
SUNSET
HOUR SCALE
1
2
3
4
5
JUL.
AUG.
SEPT.
OCT.
NOV.
DEC.

No. 10, APRIL, 1901.

CONCLUSIONS RELATIVE TO THE CULTURE OF SUGAR BEETS.*

BY W. P. HEADDEN.

* This appears as a Summary of Bulletin 63. A Resume of the Publications of the Colorado Agricultural Experiment Station, and is not here reprinted.

No. 11, APRIL, 1901.

HOW TO FIGHT THE CODLING MOTH.

BY CLARENCE P. GILLETTE.

Many orchardists spray for the codling moth and still grow very wormy apples. The writer knows of an orchard near the Experiment Station that was sprayed with an arsenical mixture three times last summer and in which fully 80 per cent. of the fruit was wormy at the time of picking in September. Another orchard in the same neighborhood was sprayed twice and had less than 2 per cent. of wormy fruit at picking time. What made the difference? Why is it that one man sprays his orchard and has very little wormy fruit and his neighbor, who also sprays, has nearly all of his apples wormy? This is a question often asked and frequently difficult to answer satisfactorily. That a reason exists for the different results there can be no doubt. The object of this paper is to give the best directions that we can at present for the successful treatment of this insect. Perhaps it will explain to some why they have not met with better success in the past.

WHEN TO SPRAY.

No date can be fixed upon, yet spraying *must be done at the right time* if the best results are to be obtained. The *right time* is immediately after the blossoms fall and before the calces of the forming apples close. If there are belated blossoms on the trees after the great mass of bloom has

fallen, do not wait for them if some of the calces are closing. If the trees do not all bloom nearly together, spray the early blooming trees first and then in a few days spray the others. Repeat the application in one week, or, at the latest, ten days.

HOW TO SPRAY.

Be thorough with the work. It will take more time and material, but if spraying for this insect will pay at all it will pay best to do the work well. Use a nozzle that throws a medium fine spray, not a mist, and direct it so that the liquid will be thrown *into* every blossom or calx. A misty spray will not carry as well into the blossoms. To make a thorough application, it will be necessary to direct the spray from, at least, two sides of the tree, and if the tree is large, it will be almost necessary to apply from all four sides. In many orchards the trees are so closely set, so large, and poorly pruned, that it is impossible to make a thoroughly good treatment for the destruction of codling moth larvæ.

The one who directs the nozzle for the spraying will find it a great advantage to be elevated as high as the bed of a wagon box at least. If the trees are large, it will be well to use a step-ladder or a dry goods box in the wagon to elevate him still more.

NUMBER OF APPLICATIONS.

Orchardists differ widely in opinion as to the number of applications that should be made. Some, noticing that the worms are most abundant late in the summer, think that spraying should be continued throughout the season of growth and report excellent results from spraying five or six or more times. However, it is the opinion of those who have tested the matter most thoroughly at the various experiment stations of the country that it does not pay to spray more than twice, if the two applications are properly made at the best time.

POISON TO USE.

Here again opinions differ. Probably Paris green is as effectual as any if well applied and if the liquid is kept thoroughly agitated during the spraying. Scheele's green would probably be as effectual as Paris green, is cheaper, and remains in suspension in water better. London purple and arsenate of lime are readily kept in suspension in water but are slower in their action than the above mentioned

poisons, and probably less effectual in their death-dealing power. They have the advantage of being very cheap. Arsenate of lead is kept in suspension without difficulty and is remarkable for its adhesive quality and its entire harmlessness to foliage unless used in great excess. It kills slowly and its value for the destruction of the codling moth has not been very definitely determined.

PREPARATION OF THE POISONS.

Paris green, Scheele's green and London purple may be used in the proportion of 1 pound to 160 gallons of water. It is best to mix the poison in a small amount of water first and then in the full amount for which it was prepared. For each pound of poison used, add to the water one or two pounds of freshly slaked lime. This will lessen the liability of the poison to burn foliage.

Arsenate of lime, by the Kedzie formula is prepared as follows: "Boil two pounds of white arsenic and eight pounds of salsoda for fifteen minutes in two gallons of water. Put into a jug and label 'poison'. When ready to spray, slake two pounds of lime and stir into 40 gallons of water, adding a pint of mixture from the jug."

If this formula is followed, be sure to use a full measure of fresh lump lime, otherwise some of the arsenic will be left in solution in the water and will kill the foliage.

A somewhat simpler method of preparing arsenate of lime is to boil together for three-quarters of an hour 1 pound of white arsenic, 2 pounds fresh lime, 1 gallon water. Use one quart of this to an ordinary barrel of water (about 40 gallons).

If a stock solution of this poison is kept, be sure to label it plainly "poison," and it would be well to put in some kind of coloring matter besides.

If arsenate of lead is employed, use not less than one and one-half pounds to 50 gallons of water. Lime need not be added to this preparation.

If more than two applications are made, do not use the poisons in more than two-thirds of the above strengths after the second treatment.

OTHER REMEDIAL AND PREVENTIVE MEASURES.

Bandages of burlap or other cheap fabric placed about the trunks of the trees from the middle of June till September will collect large numbers of the larvæ which gather beneath them for the purpose of changing to the pupa and then

to the moth stage. If these bands are removed once in a week or ten days, quite a large percentage of the worms may be collected and destroyed. A bandage four inches wide and having two or three thicknesses of cloth is of good size and may be held in place by means of a single carpet tack thrust through the overlapping ends into the bark of the tree. A band thus held may be quickly taken off and replaced.

Gathering and destroying fallen fruit, either by hand or by means of hogs or sheep turned into the orchard, will help some to keep the codling moth in check, but most of the worms leave the apples before they fall. After apples have lain on the ground for three or four days almost no worms can be found in them.

Protect cellar doors and windows with screens wherever apples are kept so that moths hatching in the cellar cannot escape to the orchard.

Clean culture and the removal of all rubbish in and about the orchard will make it more difficult for the worms to find a suitable hiding place for the winter.

Scraping the loose bark from trunk and branches will also remove many safe hiding places for worms during winter.

No one should be discouraged because he does not meet with as complete success in the use of the above remedies as he had hoped the first year. He who persistently and intelligently uses them through a series of years will be almost certain of a degree of success that will convince him of their value.

Bulletin 65. September, 1901

The Agricultural Experiment Station

OF THE

Agricultural College of Colorado.

A Soil Study.

PART III.

THE SOIL.

—BY—

WILLIAM P. HEADDEN.

PUBLISHED BY THE EXPERIMENT STATION
Fort Collins, Colorado.
1901.

The Agricultural Experiment Station,

FORT COLLINS, COLORADO.

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A Soil Study:

Part III. THE SOIL.

By WILLIAM P. HEADDEN, A. M., Ph. D.

[*For convenience of reference the principal paragraphs are numbered, and a table of contents placed at the end of the bulletin.*]

§ 1. Bulletins 46 and 58 contain the results of our observations upon the effects of the mechanical condition, the "alkalis" contained in, and the general properties of this soil upon the crops grown on it. This bulletin forms the continuation of our study, and will treat of the soil itself. The preceding bulletins have treated of the crops; this will have nothing to do with them.

The crops grown were, with one exception, sugar beets. This soil, judged by the crops it has yielded, is abundantly rich in plant food. The crops obtained are more conclusive in regard to this point than the indications of the chemical analyses. In this case, however, the two methods of judging lead to the same conclusion, *i. e.*, that any failure of plants to grow is not due to a lack of fertility.

REASONS FOR CHOOSING THIS PLOT OF GROUND.

§ 2. The choice of this particular piece of ground for study was determined by the fact that it was considered to be the most strongly alkalized plot to be found on the College Farm. It had been cultivated previously, but no crop was obtained. It was next set to forest trees, but the most of them died, only a very few surviving the first season, and the surviving plants were unhealthy. The roots of the young trees which were set out in the spring of 1896 were blackened by the soil, and did not seem to have grown at all. There is no reason to doubt but that this was due to the soil conditions, for the mortality among the plants varied with the soil in which they were set. In portions of this forestry plot, which included the plot made the subject of this study, the young trees lived well, whether they made trees or not. The soil and its condition, however, was quite different. This fact eliminates several questions, such as the condition and vitality of the young trees at

the time of setting, the manner of setting and their subsequent treatment. The failure of the forestry experiment in this portion of the plantation was quite certainly due to the soil. To be more specific, it was due either to the salts present in the soil, to the soil being so wet as to prevent a sufficiently free access of the atmosphere, or to some other unfavorable condition. The presumption was that such large quantities of salts as were evidently present were quite sufficient to prevent, by their direct action, the development of the plants without considering their effect upon the soil.

OUR ORIGINAL OBJECT EXTENDED.

§ 3. The primary object of the study was to determine, if possible, the effects of these salts upon certain crops, to see if their accumulation could be prevented or hindered by cropping, or even removed by cropping to sugar beets after they had accumulated to the extent of producing a decided alkalization of the soil. As we stated in Bulletin 46, the beet crop did not remove more soda salts from the soil under these conditions than under ordinary conditions, and it became necessary to extend our study in order to obtain an answer to our inquiry as to how we could ameliorate such conditions. The question assumed such shape that we found ourselves almost compelled to address ourselves to the study of the soil itself.

THE APPLICATION OF GYPSUM NOT ADVANTAGEOUS.

§ 4. There is a general impression entertained by some that the application of gypsum to our alkalized soils would mitigate the bad effects of these salts. This opinion has found some support from the results of its use in California. The cases are entirely different. We have not the conditions that the Californians have, and the benefits obtained by the application of gypsum in their case, will not appear in ours. The character of our "alkali" is such that we cannot expect any benefit from the use of gypsum. In our particular case its addition would be a waste of material and a loss of labor, the soil being already so full of this salt that it can easily be recognized as crystalline aggregates disseminated through the soil, often giving it a mottled appearance. The addition of more gypsum under such conditions would be utterly useless.

THE CHARACTER OF THE SOIL.

§ 5. The soil itself, as was stated in Bulletin 46, varies in its character from a loamy soil with a calcareous, clayey subsoil, to a fine alluvium resting upon a stratum of gravel, separated from it by a rather compact clay, but with no proper hard pan. The whole soil is very retentive of moisture, and it is difficult to determine whether there is any direct draining of the water from the alluvial soil above into the gravel stratum below or not. The configuration

of the surface would justify the assumption that there is no hydrostatic pressure upon the water in the gravel stratum; at most it can scarcely be enough to force the water through the clay into the soil above. This would lead us to the surmise that the water in the gravel may be entirely different from the water in the overlying soil. Analyses made in the early part of our work corroborated this view.

DRAINAGE.

§ 6. The drainage of the area, of which the plot under observation forms a part, is into the Cache a la Poudre river, at a point about one and three quarters miles below the town of Fort Collins. There is at present an open ditch running through this swale for a considerable distance, and the College management has laid tile drains for a long distance, serving to extend the drainage system almost to the line of the College property. The lateral drains are laid with four inch tiles; the main drains with six, eight and ten inch tiles. On the lower portion of the property there are two drains, laid with eight and ten inch tiles. These drains are parallel for a portion of their length and in part divergent.

§ 7. A study of the country shows that this swale was formerly the bed of a considerable stream formed by the union of streams issuing from the foothills through Spring, Dixon, Soldier and probably what is now the Poudre canon. This fact accounts for the strata of gravel and sand encountered in and along the margins of the swale.

The foundation of the Chemical Laboratory, situated on the north side of the swale, had to be put down to a depth of 20 feet on account of quicksands. At this depth, however, the workmen encountered a stratum of course gravel.

The fall from the plot of ground under observation to the Poudre river is about 150 feet, more rather than less. This old water course is now filled up. Ten or twelve years ago this plot of ground was very wet and boggy, the principal vegetation being cat-tails. This condition was undoubtedly due to the character of the soil, which, as I have stated, is very retentive of water.

ORIGIN OF THE SOIL.

§ 8. The source of this soil is evident and will not account for the alkali salts or its physical properties. The gravel, where there is any at all, is clearly granitic, and can not be the residue from the breaking down of the younger formations of the foothills and plains. The mechanical analysis of the soil shows that even the finest sand is granitic and has been derived from the mountains within the foothills, carried and deposited by the waters which at one time had this swale for their bed. The only evidence that any of the

soil material is of different origin is the occurrence, now and then, of a fragment of an impure limestone, which lies just out side the first hogback and belongs to the Fort Benton group or of sandstone belonging to the Juratrias. These fragments are quite rare and are the only definite proof that I have discovered that any portion of the soil has been derived from any other source than the granitic area of the mountains proper. The abundance of mica and red orthoclase in the coarser portions of the soil, and even in the silt, leaves no doubt but that this is the source of the material.

Some of the material may be the residue of strata belonging to formations of later or post cretaceous times, whose removal by waters, now represented by the Poudre river, has left some of this material. This is undoubtedly true of much of the plains soil, but probably only to a very limited extent of the soils of these old water courses.

SOURCE OF THE ALKALIES.

§ 9. The alkalies are not so easily traced. The explanation offered for the presence of alkalies in the soils of arid regions is as true here as elsewhere, but these general facts are not applicable in the explanation of the particular cases with which we meet in Colorado agriculture. It is a well known fact, one long since recognized, that the shales of several of the cretaceous groups contain a remarkable amount of these salts, designated by the general term alkali, including sodium, calcium, and magnesium as sulfates, carbonates, and chlorids.

GENERAL COMPOSITION OF THE ALKALIES.

§ 10. Analyses of incrustations from various parts of the State, and of waters from both ordinary and artesian wells, show the very general distribution of these salts. They also corroborate the observation of their presence in the shales and other rocks which, whatever may have been the origin of the salts, serve at the present time to furnish the alkalies to the waters percolating through them. The following figures, representing the general composition of the alkali, will serve to illustrate the general application of the assertion. An incrustation from the College Farm showed:

Calcic sulfate	25.451 per cent.
Magnesic sulfate	19.798 per cent.
Sodic sulfate	41.748 per cent.

The ground water from about five feet below the surface yielded an abundant residue, composed of:

Calcic sulfate	35.648 per cent.
Magnesic sulfate	28.750 per cent.
Sodic sulfate	11.393 per cent.

A surface well, 28 feet deep, yielded water giving a large residue, of which these salts formed 74 per cent., as follows:

Calcic sulfate	15.206 per cent.
Magnesic sulfate	29.059 per cent.
Sodic sulfate	29.865 per cent.

An artesian well, supposed to tap a water bearing Dakota sandstone and having a depth of 845 feet, furnished a water carrying 79 grains of total solids in each imperial gallon, of which 83 per cent. consisted of these salts, as follows:

Calcic sulfate	12.036 per cent.
Magnesic sulfate	10.473 per cent
Sodic sulfate	60.758 per cent.

It is evident, not only from observation, but as is also indicated by such figures as these, that it is not at all necessary for the agriculturist to question in regard to the immediate source of the salts included under the general term alkali. They are so abundantly present in the rocks and waters, even in waters from considerable depths, that there is no need to seek further for their supply. The questions relative to their more remote origin and how it happens that the shales and even the sandstones are impregnated with these salts can be left to the geologist without serious inconvenience in studying the questions with which our agriculture has to deal. They are here, and in cases where the drainage of any larger area accumulates in a small basin, alkali salts will be brought together and under proper conditions will appear as an incrustation. This does not take place unless the water plane is at a less distance from the surface than that through which capillarity can raise the water in the particular soil. This was the case in the soil in question, the incrustations accumulating to a maximum thickness of upwards of one half inch. The incrustations being most marked in early summer, but also during the winter when the condition of the weather was favorable.

Relative to the origin of such quantities of sulfates in these rocks and soils, the possible supply is abundant, for throughout the mountain masses we find sulfids disseminated everywhere and we have an almost inexhaustible source of sulfuric acid for the formation of alkali in the gypsum which is so abundant in our Jurassic and other formations.

THIS STUDY LARGELY A MINERALOGICAL ONE.

§ 11. It is to be understood that throughout this bulletin the term soil is used sometimes to mean all of the factors conducing to make up the unit which is expressed by this term; at others in a much narrower sense, meaning to include only a part of the same.

Most of our analyses, for instance, have to do with only one phase of the subject and that almost exclusively a mineralogical one which may practically be designated as a somewhat indefinite study of the decomposition products of feldspar, principally a red orthoclase. It may be a little humiliating at this juncture to make so uncomplimentary a statement concerning this part of our work, but it is scarcely more. This is very plainly suggested by the results of the mechanical analysis which, as already stated, shows this mineral to be the principal one from which the potash can be derived. The small amount of mica in the soil would, even if the mica were easily attacked and altered, contribute but a very small amount of potash or lime, it being very subordinate in quantity. The analyses of the separate parts of the soil as obtained in the mechanical analysis will be shown to suggest the same fact so forcibly that it amounts almost to absolute proof that in our samples we have to do with an altered feldspar.

THE EXPERIMENTS COVER TOO SHORT A PERIOD.

What the effect of growing three crops on this soil may have been is scarcely shown by so short a series of experiments; that is, the results are not large enough to be measured by the means at our command. Even if we should confine the effect to the clay this would still be true. This, however, cannot, as we will show, be justly done, for the feldspar certainly yields fresh quantities of potash to the soil. This mineral is so finely divided, or enough of it is, that even the rain water can and undoubtedly does take a perceptible quantity of this compound into solution.

POTASH IN FELDSPAR AVAILABLE.

§ 12. We shall show by direct experiment that the oat plant, for instance, can appropriate potash from this mineral when it is finely powdered, even in cases in which the mineral is perfectly fresh and the whole work of decomposition has to be done during the period of growth of the plant, perhaps by the roots of the plant itself. The theory of the formation of zeolitic minerals, to serve as the conveyors of the potash, etc., from the more stable minerals to the plant, cannot very well be appealed to, at least as necessary. My experiments do not show that zeolitic compounds are not formed, but they do show that if they are formed, their formation takes place so rapidly that perfectly fresh, but finely pulverized, feldspar becomes an available source of potash in the short period required for the growth of the oat plant. I do not mean to say that finely powdered feldspar will yield potash so rapidly that it will furnish a supply adequate to the production of a crop, but that it will furnish in the aggregate a very considerable quantity of this element. It is a well known fact that this mineral yields potash to water and it

was to be expected that growing plants might obtain some potash from this source, but my experiments show that this plant may perfect its growth, obtaining all of its potash from the pulverized feldspar.

§ 13. This fact is of great importance to our Western agriculture, especially to the agriculture of the eastern slope of the Rocky Mountains and eastward to the State line, as the irrigable lands are composed largely of granitic materials and consequently contain a more or less considerable quantity of feldspar, whose decomposition yields, slowly it may be, but a continuous supply of this very important compound. The partially altered mineral possibly presents a greater degree of resistance to further decomposition than the fresh mimeral does to the first attack, but this will affect only the rate of the supply, for we know that this mineral eventually suffers complete decomposition. These soils, or mixtures of minerals, quartz, feldspar and mica, are well preserved because our climatic conditions have not been favorable to their decomposition, either directly or through the decay of organic matter. The rate of change under more favorable conditions, those of irrigation with an increase of vegetable matter, may be more rapid, but it will still be comparatively slow; not too slow, however, to make its results a factor in the supply of potash for our cereal crops.

§ 14. A question arises in this connection relative to the course which the decomposition of the feldspar takes, and whether an experiment with powdered feldspar is comparable with the conditions which prevail in the soil. There is no question but that they are not wholly so. The decomposition may go on either more rapidly or less rapidly in the soil than in the experiment with a mixture of sand and feldspar in boxes. Still the results are, in a measure, comparable. The soil contained from 16 to 28 per cent. of dust, the particles of which have a diameter of less than 0.01 millimeter, and while, as previously intimated, the original feldspar present may have already been so changed that its further decomposition may be somewhat slower than at some previous stage of its history, it has not been removed from all further action of the solutions in the soil, the plant roots and other agents.

In experimenting with the feldspar, the whole of it was reduced to powder, whose largest grains were less than one millimeter in diameter, and of which rather more than 33 per cent., by weight, consisted of particles of less than one quarter of a millimeter in diameter. The feldspar was pulverized to render it more readily attacked, and to reduce its particles to a size comparable with the size of the finer soil grains.

FELDSPAR A SOURCE OF HYDROUS SILICATES.

§ 15. The water in the soil also shows that such changes are

going on continuously, for they are constantly removing salts in solution, the supply of which is, in part at least, maintained by the decomposition of the constituent minerals of the soil. If there were no such supply of these salts, they ought to have diminished in quantity to a very small fraction of that which we now find. The formation and continuous presence of highly reactive, hydrous silicates within the soil may be accepted as established, but back of this, as well as of that of clay, whether kaolinitic or colloidal, are the decompositions of which these compounds are themselves but products. In the case of the soils in question, the original minerals whose changes have furnished the materials for these zeolitic compounds are preeminently the feldspars of the granites of the front range. Traces of igneous rocks are found, but their part in the formation of these soils is so subordinate that they may be neglected. That the ground waters, already rich in salts, participate in producing these changes is very probable. The uniform presence of potash salts in the ground water is presumably due in part to this fact. The elimination of potash from the soil in the form of nitre, potassic nitrate, will account for the presence of some, but not for the whole, of the potash present in the ground water. The presence of silicic acid in all of the water, amounting in some instances to about 2 per cent. of the total solids, is likewise suggestive of the decomposition of silicates, yielding, among other products, new silicates soluble in water. The silicic acid present in the water analyses, which will subsequently be given, was in solution either as hydrated silicic acid or in the form of soluble silicates.

A very striking instance of the presence of silicic acid in water came under my notice a few years ago. The water was a very excellent spring water, free from sediment, limpid, and had a temperature of 53° F. The silicic acid present amounted to 25 per cent. of the total solids held in solution. I do not know whence this silicic acid was derived, but most probably from the decomposition of some feldspar, as potash and soda were the next most abundant constituents of the residue obtained from the water. The chemical changes producing such a solution as this in a spring water are quite sufficient, even though they may be modified in many ways, to account for the silicic acid found in the residues obtained from ground waters.

SOME SALTS ARE FORMED IN THE SOIL.

§ 16. We cannot distinguish between the salts which have been dissolved out of adjacent localities and brought by the flowing waters into the area where it is found, and those which have been formed in the latter soil. In the former case they may contribute to bring about new changes, in the latter they will be products of the changes ordinarily going on in that soil, and aid in giving

distinctive properties to it. These would remain if the others should be eliminated.

§ 17. The relative amount of magnesic salts which are present in the ground waters before and after the soil has been cultivated, also before and after the application of manure, indicate that there is a series of reactions taking place which result in eliminating these salts as end products. The growing of crops, the cultivation and irrigation of the soil, also the application of manure, accelerate these changes. The readiness with which these reactions take place, especially if they be beneficial to the crop, must, to a considerable extent, be a measure of the soil's fertility.

THE BIOLOGY OF THE SOIL NOT STUDIED.

§ 18. The soil is not only the theater of a wide range of chemical reactions, some dependent upon and some independent of the living organisms present, but it is also the home of an abundant microscopic life, constituting a veritable world of itself.

§ 19. The biological conditions of the soil ought, in this study, to have been taken up with thoroughness, but it has been impossible. We will present the results obtained by such study as we have been able to devote to the soil in the following pages.

§ 20. The purely agricultural features of this study have already been given in Bulletins 46 and 58. These bulletins have treated exclusively of the crops grown on the soil, especially of the effects of the alkali on the growth and ripening of the plant, on the amount of ash constituents taken up, etc. In this bulletin we shall treat of the soil, and in a subsequent one of the ground waters, the irrigation water and its changes.

THE PHYSICAL CHARACTER OF THE SOIL.

§ 21. Beginning at the west end of the plot the soil is a light loam. This passes into a paludal soil rich in alkali, succeeded by a gravelly, clayey soil, which has resisted treatment to a greater extent than any other portion of the plot. The most eastern section of the plot is the lowest, the wettest, and, judging by the abundance of the salts which effloresce, the most strongly alkalized one. The extreme western section is the only one in which there is a subsoil within six feet of the surface. The character of the eastern most section was that of a very tenacious, alkalized clay, which, when moulded to a form and dried, became exceedingly hard. It was a most unpromising soil to attempt to do anything with. The plot has a slope to the eastward of about four feet in 600. There is a stratum of coarse sand and gravel underlying the whole of the plot at a depth of about six feet. The surface is fairly even, with a slight depression running diagonally from near the southwest corner to the north side, a little west of the centre.

PREPARATION OF THE SAMPLES.

§ 22. Six samples of this soil were taken in the spring of 1897, before it was plowed for the planting. These samples were taken with care to obtain samples representing the soil. Sections $8'' \times 8'' \times 10''$ were cut out and prepared for analysis. These sections were dried, all lumps being broken by hand from day to day as they became dry enough to be rubbed to pieces in this manner. When drier, and too hard to be so manipulated, they were rubbed in an iron mortar, the mortar being filled so full that pulverization did not take place. In order to be able to study the rock fragments still remaining in the samples, they were passed through sieves from one quarter inch to one twenty-fifth inch mesh. All that passed through the one twenty-fifth inch or one millimeter mesh, was preserved as the sample of fine earth. The coarser portions, six in number, were thoroughly washed and their weight and character determined. The samples were designated by the letters A, B, C, D, E and F. The successive parts are designated by the subscript figures 1, 2, 3, etc.

SAMPLE A.

§ 23. This sample was taken from the east end of the plot, 40 feet east of well A, the worst section of the plot. The sample was divided into the following parts:

Parts.	*Meshes to the Square Inch.*	*Character of the Fragments.*	*Per Cent.*
A_1	4	Quartz, granite, mica, limestone, feldspar	0.68
A_2	9	Quartz, granite, brown sandstone, limestone, feldspar	1.17
A_3	36	Quartz, granite, mica, oxid of iron, limestone, feldspar	2.19
A_4	144	Quartz, granite, iron oxid, limestone, feldspar	4.35
A_5	196	Quartz, mica, feldspar	1.92
A_6	625	Quartz, mica, iron oxid and feldspar	6.31
		Fine earth	83.38

SAMPLE B.

§ 24. This sample was taken 50 feet west and two feet north of well A. This sample is from the edge of the gravelly, clay knoll, on the north side of the plot, and east of the centre:

Parts.	*Meshes to the Square Inch.*	*Character of the Fragments.*	*Per Cent.*
B_1	4	Quartz, brown sandstone, mica, feldspar	4.54
B_2	9	Quartz, brown and red sandstone, mica, feldspar	3.40
B_3	36	Quartz, brown and red sandstone, iron oxid, feldspar	6.39
B_4	144	Quartz, brown and red sandstone, iron oxid, mica, feldspar	6.83
B_5	196	Quartz, mica and feldspar	3.14
B_6	625	Quartz, mica, feldspar	11.95
		Fine earth	63.75

SAMPLE C.

§ 25. This sample was taken 45 feet west and three feet north

of well B. This sample is from the eastern edge of the depression running diagonally across the plot and western edge of gravelly knoll.

Parts.	Meshes to the Square Inch.	Character of the Fragments.	Per Cent.
C_1	4	Quartz, granite, feldspar	13.77
C_2	9	Quartz, granite, limestone, iron oxid, feldspar, red and brown sandstone, mica	6.63
C_3	36	Quartz, granite, limestone, sandstone, mica, feldspar	9.78
C_4	144	Quartz, mica, limestone, sandstone, feldspar	7.53
C_5	196	Quartz, mica, limestone, feldspar	2.63
C_6	625	Quartz, mica, feldspar	9.08
		Fine earth	50.58

SAMPLE D.

§ 26. Sample taken 25 feet west and three feet north of well C. This sample represents the low portion of the west half of the plot. It is quite wet and strongly alkalized.

Parts.	Meshes to the Square Inch.	Character of the Fragments.	Per Cent.
D_1	4	Quartz, granite, feldspar	1.50
D_2	9	Quartz, red and brown sandstone, limestone, feldspar	0.67
D_3	36	Quartz, granite, sandstone, limestone, feldspar	1.86
D_4	144	Quartz, sandstone, limestone, iron oxid, feldspar	2.80
D_5	196	Quartz, limestone, mica, feldspar	2.08
D_6	625	Quartz, mica, feldspar	8.81
		Fine earth	82.27

SAMPLE E.

§ 27. Sample taken three feet west and three feet north of well D. This sample represents the western end of the plot.

Parts.	Meshes to the Square Inch.	Character of the Fragments.	Per Cent.
E_1	4	Quartz, granite, feldspar	0.71
E_2	9	Quartz, granite, feldspar	0.29
E_3	36	Quartz, granite, limestone, sandstone, iron oxid, feldspar	1.25
E_4	144	Quartz, mica, limestone, iron oxid, feldspar	3.38
E_5	196	Quartz, mica, limestone, feldspar	2.99
E_6	625	Quartz, mica, feldspar	11.37
		Fine earth	80.01

SAMPLE F.

§ 28. This sample is the subsoil corresponding to sample E.

Parts.	Meshes to the Square Inch.	Character of the Fragments.	Per Cent.
F_1	4		0.00
F_2	9		0.00
F_3	36	Quartz, limestone, feldspar	0.03
F_4	144	Quartz, limestone, feldspar	1.58
F_5	196	Quartz, limestone, feldspar	1.84
F_6	625	Quartz, limestone, feldspar	9.34
		Fine earth	87.21

MECHANICAL ANALYSIS OF THE "FINE EARTH."

§ 29. The beaker elutriation of the fine earth gave the following results:

TABLE I.—MECHANICAL ANALYSIS OF THE FINE EARTH.

SAMPLE.	Hygroscopic Moisture.	Temperature of Absorption.	Water Capacity.	Coarse Sand. 1.0 to 0.5 mm.	Medium Sand. 0.5 to 0.25 mm.	Fine Sand. 0.25 to 0.05 mm.	Silt. 0.05 to 0.01 mm.	Dust. Less than 0.001 mm.	Clay by Difference.	Ignition.
Soil A	6.40	15°	51.05	4.459	5.392	26.078	19.527	27.878	8.314	8.351
Soil B	4.50	15°	36.50	8.114	10.147	35.593	12.386	23.653	4.582	5.543
Soil C	4.20	15°	44.22	7.318	6.940	20.518	20.828	27.633	7.876	8.887
Soil D	5.90	15°	40.54	6.254	7.197	25.894	24.748	21.704	6.013	8.190
Soil E	3.40	15°	36.84	7.070	9.227	29.947	25.573	16.642	3.534	8.007
Soil F	3.50	15°	42.34	6.380	7.409	23.736	30.604	19.488	5.552	7.673
Loess Soil. Weld Co.	......	......	......	1.172	3.737	45.707	27.721	10.565	5.217	5.881
Loess Soil. Larimer Co.	......	......	......	0.965	2.073	24.451	49.714	11.797	4.567	6.433
Red Soil. Clay Soil. Red Beds.	......	......	......	4.411	11.872	27.943	31.592	13.793	4.600	5.789

THE MINERALOGICAL CHARACTER AND SOURCE OF THE SOIL PARTICLES.

§ 30. The sand grains in the different samples consisted of quartz, feldspar and some flakes of mica. The quartz grains show plainly the deposition of oxid of iron upon their surfaces, in checks and depressions in the grains. The deportment of the sand, and more particularly the still coarser portions, warns us that we cannot conclude that the sand particles owe their origin to the red beds, because of their color after ignition, for there is enough organic matter coating the grains to cause blackening upon heating, and this may account for the presence of the iron oxid which becomes evident upon igniting the sands. There is nothing distinctive enough, so far as I have observed, about the sand grains to justify one in asserting that they did or did not come from the juratrias, or Dakota sandstones, or are directly due to the breaking up of the granites. The presence of so large an amount of feldspar and mica, neither of which is present in the sandstones of these formations in such quantity, is strong proof that practically the whole mass is derived directly from the rock masses of the mountains which lie immediately west of us, and consists of granites, gneisses and mica schists.

§ 31. While I believe myself justified in making the state-

ment that the most of the rock material of this soil came directly from the mountain masses in geologically recent times, I am fully aware that the disintegration of the red sandstones, and to a less extent the conglomerates of the red beds, could give rise to a very similar mixture of rock fragments. The following facts show this plainly. A sandstone belonging to the upper part of the Upper Wyoming, of loose texture and easily disintegrated by soaking and judicious rubbing, without any grinding up of its particles, gave me the followitg mechanical analysis:

Sand grains having a diameter greater than two millimeters, 1.40 per cent.; greater than one millimeter, 26.80 per cent.; less than one millimeter, 62.70 per cent.; cementing material, oxid of iron, calcic carbonate, etc., 9.10 per cent. The sand grains were principally quartz, but there were some grains of feldspar and a few flakes of mica. In regard to the fineness of the particles, it will be noticed that practically 63 per cent. of the mass of the sandstone was as fine as that division of the soil designated "fine earth," and that this percentage is as great or greater than that of the fine earth in two of our soil samples. The alkalies in this sandstone were determined and found to amount to 1.30 per cent. of the sandstone; potash constituting 1 per cent., and soda three tenths of 1 per cent. The cementing material, mostly calcic carbonate and oxid of iron, contained a small amount of these constituents, potash 0.025 per cent., soda 0.053 per cent., calculated on the sandstone, not on the weight of the cementing matter. The alkalies were also determined in a sandstone from the Lower Wyoming, and found to equal 2.563 per cent. of the sandstone; potash 0.924 per cent., soda 1.639 per cent. The potash in each of these cases amounts to about 1 per cent., and is contained almost wholly in the sand grains, among which, especially among the larger ones, feldspar grains are easily recognizable. These sandstones do give rise to a soil whose elutriation would yield a mixture of sand grains somewhat similar to that with which we have to do in this study. The characteristics of the soil formed by the disintegration of these sandstones are so markedly different from those of the one we are considering, that they are not even suggested as the possible source of the material, except by the most thorough washing of the soil formed from them.

§ 32. The statements relative to the mineralogical character of the different classes of soil particles are applicable to all of the soils which I have analyzed or examined with care, whether close to the mountains or as far east as the State line, excepting the soils of the valley lying between the hogback formed by the Dakota sandstone and the mountains proper. This area, corresponding to the outcrop of the red beds, is not wholly covered by this granitic soil. There are doubtlessly some sections where the surface soil is derived from younger formations, the particles of which have not

been transported from the mountains by the streams or waters which have given the country its present contour, but are disintegration products of formations composed of material similar to that brought from the mountains by the streams of later times.

The particles of more than 0.5 millimeters diameter are for the most part rounded, but this is not the case with those less than .25 millimeters, nearly all of which are sharply angular.

§ 33. It may appear to many, especially to such as have an acquaintance with the occurrences of loess and other formations of the plains, the mineralogical constituents of which are often identical with those given for these soils, that the latter, like the former, may be the product of other disintegrations than that of the granites of the Colorado range. There is nothing in their composition to preclude their having been derived from some other source. Their geographical distribution makes it probable that material similar to this composing our soils has been derived from other mountains than those lying near to us. It seems reasonable, however, to assume that the near and very extended range has furnished essentially all of the material going to make up these soils. There may be a doubt entertained that the quartz, feldspar and mica given in the preceding table were derived from the present mountains, but there can be no question regarding the source of the fragments of red and brown sandstones, or of the impure limestone; these are the products of the disintegration of the red beds and of the Fort Benton limestone.

SOIL COMPARED WITH LOESSIAL SOIL.

§ 34. There is given in the table of mechanical analyses, one of a loessial soil from Weld county. This soil, according to the mechanical analysis, has a very different composition from the soils given above. It is characterized by a high percentage of fine sand and low percentages of dust and clay, but mineralogically the sand and coarser parts are the same as in the other soils, *i. e.*, quartz, feldspar and mica. The mica, though still subordinate in quantity, is more abundant in the loessial soil than in the others. It seems to be a general rule that the farther back from the river we get, or higher up on the plains, the greater is the percentage of fine sand present in the soil.

§ 35. I have not attempted to determine the ratio between the grains of feldspar and quartz in these soils, but others have determined this ratio in the loess, for which the approximate determination is given as: Quartz, 40 per cent.; feldspar, 50 per cent.; other constituents, 10 per cent.* The minerals making up the other 10 per cent. were, in the case of the Weld county loessial soil,

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* Emmons' Geology of the Denver Basin in Colorado, p. 262.

mica, magnetic oxid of iron, etc. I have not determined, by actual count, the grains of quartz and feldspar, but my judgment is that there is more quartz in the sands that I have separated from these soils than is indicated by the percentage given in the analysis quoted, viz., 40 per cent. It is to be expected that the mechanical composition of soils will vary from place to place, and yet the table shows a greater agreement than we would expect; the sample of loessial soil from Weld county and of loess from Larimer county being the only ones which show wide deviations in the percentage of any class of soil particles. Not only the mineralogical, but also the chemical examination of these soils, indicate a rather uniform composition, though the samples were taken from widely separated localities. By chemical analysis is here meant the analysis of the whole mass, a mass analysis, and not a soil analysis as it is made for agricultural purposes.

§ 36. Dr. S. F. Emmons, writing of the loess in the "Geology of the Denver Basin in Colorado," says that it contains in all cases a large proportion of sand, separable by washing, whose grains are usually under a millimeter, but rarely less than a tenth of a millimeter in diameter. The mechanical analyses of the loessial soils show 43 and 64 per cent. of the mass to have a diameter of less than five one hundredths of a millimeter. The mechanical analysis of this soil shows 47.40 per cent. of material, the clay not included, whose grains have a diameter of less than one tenth of a millimeter, and which differ from the coarser portions only in the degree of their comminution. The loessial soils given agree in having high percentages of fine sand and silt, and lower percentages of dust and clay than ordinary soils; but our results do not agree with Dr. Emmons' observation that the grains of sand in loess are rarely less than one tenth of a millimeter in diameter.

SIMILARITY OF THE PARTICLES AND COMPOSITION OF SOILS.

§ 37. The fine sands are, in every case, much more angular than the coarser, due to the manner in which the water has effected their transportation, the larger having been rounded by rolling or by attrition while in suspension. The loessial soils show this characteristic as markedly as the other soils examined. There is so great a similarity in the mineralogical composition of our soils, though they vary in appearance, that it is a matter of some surprise that they should differ so extremely in properties. The chemical analysis of the soils, mass analysis, does not change this phase of the matter at all. The following analyses of samples taken from rather widely separated localities, may serve to illustrate this:

TABLE II.—MASS ANALYSES OF SOME SOILS.

	Prairie Soil, South of Agricultural Hall. Surface.	Soil A. Taken 10″ deep.	Loessial Soil. Weld County. 21⅓″ deep.	Loessial Soil. Larimer County. 6 ft. from top.	Loess. Cheyenne, Wyo.*
Silicic Acid	69.356	64.745	72.550	67.836	67.100
Sulfuric Acid	0.041	0.827	0.023	0.025	....
Carbonic Acid	0.016	1.208	0.368	0.888	3.670
Chlorin	0.006	0.014	Trace.	0.022	....
Phosphoric Acid	0.466	0.112	0.331	0.411	0.110
Potash	2.248	2.295	2.479	2.497	2.680
Soda	1.215	1.184	1.498	1.311	1.420
Lime	1.645	2.789	1.075	2 481	5.880
Magnesia	1.412	1.819	1.245	1.740	1.240
Ferrous Oxid	....	....	....	....	0.310
Ferric Oxid	5.424	4.475	4.420	5.255	2.520
Aluminic Oxid	11.338	11.717	10.754	11.418	10.260
Manganic Oxid (br)	0.160	0.200	0.239	0.109	....
Moisture at 110° C	2.981	3.296	2.595	3.569	....
Ignition	4.044	5.402	2.311	2.287	5.090
Sum	100.352	100.080	99.888	99.849	100.280
Oxygen Equivalent to Chlorin	0.001	0.003	....	0.005	....
Total	100.351	100.077	99.888	99.844	100.280

* Analysis by Eakin's Geology of the Denver Basin in Colorado, p. 263.

I have chosen the sample of loess from Cheyenne because this is probably more nearly comparable to mine than any other at my disposal, and the locality is nearer by thirty miles than that from which the next nearest sample was taken. The sample marked loess from Larimer county was taken at a point about seven miles from the place where the sample soil A was taken. The most marked variations in the composition of these samples are, the sulfuric acid of the soil A, the carbonic acid and lime of the loess from Cheyenne. The sulfuric acid in the soil was probably present as calcic sulfate or sodic sulfate, forming a part of the "alkali" present in the soil. The carbonic acid and lime in the Cheyenne loess was doubtlessly present as calcic carbonate. This is of common occurrence in this formation; is very variable, and is not essential. With these exceptions, the causes of which are usually discernible without the aid of chemical analysis, or even a magnifying glass, these soils agree as closely as samples taken within a few feet of one another might

agree, and suggest a common origin for wide areas of our surface soils.

The alkalies are lower than one would expect, judging from the number of feldspar particles which are present, and the ratio of the soda to the potash is high, as the feldspar recognizable is very predominantly orthoclase. The silicic acid is lower than the apparently large number of quartz grains present would suggest. The orthoclase contains, in round numbers, 66 per cent. of silicic acid, while the average percentage of this acid in these soils is 68.6 per cent., which seems lower than the macroscopic examination suggests.

PORTIONS OF FINE EARTH EXAMINED.

§ 38. The loess from Cheyenne was not examined further, nor was the loessial soil from this county, but the soil A was. The fine sand, with particles from 0.25 to 0.05 millimeter in diameter, the silt, the dust and the clay were each analyzed with the following results:

TABLE III.—ANALYSES OF PORTIONS OF "FINE EARTH" OF SOIL A. SAMPLE TAKEN TEN INCHES DEEP.

	Fine Sand.	*Silt.*	*Dust.*	*Clay.*
Silicic Acid	82.024	69.247	58.204	40.389
Sulfuric Acid	0.017	0.014	0.100	7.060
Potassic Oxid	1.914	2.711	3.166	3.000
Sodic Oxid	1.926	1.851	1.323	3.134
Ferric Oxid	3.383	5.425	9.109	7.113
Aluminic Oxid	6.737	13.018	19.078	14.607
Calcic Oxid	1.746	1.488	1.480	6.059
Magnesic Oxid	0.777	1.519	2.648	3.982
Manganic Oxid (brown)	0.150	0.250	0.190	0.168
Moisture and Organic Matter	0.750	4.118	3.980	14.668
Total	99.424	99.631	99.278	100.180

The coarser parts of the soil were not analyzed, for the reasons that they are comparatively small in quantity and, on account of the large size of their particles, are not subject to those actions which liberate plant food to any considerable extent. It might have been better for a favorable presentation of results had we analyzed them, but there was so little to be gained that we did not deem it worth the work. This table shows a very decided difference in the composition of the parts separated by washing the soil. We have no basis of comparison with the loess and other soils. The series stands alone, but the results that it exhibits are so pronounced and so similar to what we would expect that we have little hesitancy in accepting it as proven that there is an accumulation of the potash in the finer portions of the soil, and a diminution of the silicic acid.

PROBABLE COURSE OF CHEMICAL CHANGES IN SOIL MASS.

§ 39. We have here probably a rough presentation of the

course of the chemical changes which take place in the transformation of a mass of rock fragments into true soil. The decomposable minerals, feldspar and mica, very subordinate in this case, are so acted upon that new minerals, having less silica but more alumina and possibly alkaline earths, are formed. The high percentage of lime in the analysis of the clay is almost certainly due to an admixture of gypsum. It is scarcely possible, owing to the manner of preparation, that the higher percentage of magnesic oxid can be attributed to a similar cause. In regard to the potash, which is even higher in the dust than in the clay, though the experienced analyst will be inclined to consider them the same, there may be a question as to the manner in which it is present. This arises from the knowledge of facts obtained from other experiments and not from the analyses. The testimony of the latter is, and it is in perfect harmony with what we know of the deportment of soil masses, that in the extremely small particles of the soil there is a tendency toward enrichment in potash. The indications of the analyses, contrary to the impressions of the writer, indicate that the maximum of this concentration is reached in the portion designated as dust, a portion whose individual particles have a diameter of less than 0.01 millimeter, or less than one twenty-five hundredths of an inch, and which constitutes 27.87 per cent. of this soil. The clay, which is still very much finer, contains, in this case, essentially the same percentage of potash, but constitutes only 8.31 per cent. of the soil. In this instance the dust and not the clay is the potash carrying silt-constituent of the soil.

§ 40. The fine particles of the dust and clay are probably not wholly composed of fine residual parts of the minerals originally composing the soil mass, but are to a greater or less extent made up of newly formed particles of precipitates, or at least of newly formed minerals, which may adhere tenaciously to the fine residual grains or form independent little aggregates which, being disintegrated by the washing of the soil, are obtained in the form of clay.

ANALYSES OF PARTS OF FINE EARTH SHOW NO DEFINITE RATIOS.

§ 41. Little can be said in regard to the ratios existing between the various chemical constituents as shown in the preceding analyses. There is, for instance, no clear and definite relation between the potash and soda, iron oxid and alumina, alkalies and alkaline earths. The iron is, taken roughly, equal to one half of the alumina. This holds true for soil A, the parts of the soil separated by washing, and of the Larimer county loess. I am inclined to think that this is an accident, in spite of its occurring in each of these six instances. It is not the case in the Cheyenne loess, and extraction with hydrochloric acid shows it to be almost wholly soluble in this agent. Macroscopic observation, especially after

ignition, shows the sand grains to be coated to a greater or less extent with this substance, oxid of iron. It does not appear as red oxid of iron on the grains before ignition, but becomes evident after. This is well seen in the color of the mass before and after ignition. This suggests the existence of hydrates of iron or organic compounds, but the loss on ignition is so small and irregular, bearing in its quantity no relation to that of the iron, that the organic compounds, if any, are very small in amount. There seems to be, as we shall see later, but a small amount of iron present in the form of a silicate insoluble in hydrochloric acid, certainly not more than may be present in a perfectly fresh feldspar. This would still be the case if the quartz sand were all deducted or considered as carrying no iron whatever. The portion soluble in hydrochloric acid, on the other hand, is rich in iron. The total loss on ignition is not unusually large, and a portion of this is water retained at the temperature of 110° C, probably in the form of hydrated oxid of iron.

SOLVENT ACTION OF HYDROCHLORIC ACID ON THE SOIL.

§ 42. The portion of these soils dissolved or decomposed by hydrochloric acid, sp. gr. 1.115, upon digestion for five days, varied from 30 to 50 per cent. The amount dissolved certainly depends upon the character of the substances present in the samples, but in this respect our samples are very uniform, containing essentially the same mineralogical components. The variation in the amount dissolved depends upon other conditions, principally upon the fineness of the soil particles, and the particular degree of their decomposition. The former condition is the more important, as the latter one is largely dependent upon it. This is quite clearly seen upon a comparison of the mechanical analyses of these samples, taking the particles having a diameter greater than 0.05 millimeter as one group, and those of less diameter as another group. The amount dissolved under the convential conditions, HCl., sp. gr. 1.115, and five days digestion on water bath, varies, but not closely, with the ratio of these two groups, into which every soil can be divided. In other words, it is the very fine particles of the soil which yield to the hydrochloric acid the elements of plant food found in the solution. This is unquestionably the case in the soil, as well as in the analysis. The decomposition of the minute particles of the minerals will take palce more slowly in the soil solutions than in the hydrochloric acid, but the order in which they will be attacked is the same, the finest first.

RESULTS OF CHEMICAL ANALYSES NOT COMPETENT CRITERIA.

§ 43. The chemical analysis does not give us a good criterion by which to judge of the virtues of a soil. It may not follow the same course of decomposition that takes place in the soil, and it cer-

tainly extends too far, that is, we can not say how long it would take to effect the same amount of change by the soil agents, as is effected by an acid solution and heat during the five days digestion, or by strong acid in ten hours.

THE SAMPLES ANALYZED.

§ 44. The samples and the manner in which they were taken have already been described. Two sets of samples were taken, one on May 13, and another on October 20, 1897. These samples were taken from the same parts of the plot, in order to make them agree as nearly as we could. We hoped that the earlier samples would enable us to ascertain the composition of the soil, the later ones to determine, if possible, the effects of cultivating, irrigating, and cropping it. The crop grown was sugar beets. The work done on the crop, both in the field and laboratory, is recorded in Bulletin 46. The whole crop, both roots and tops, had been removed before we took the samples in October.

WATER RECEIVED.

§ 45. The rainfall was about 9 inches. The amount of irrigation water used in the two irrigations given was not measured, but was estimated by an experienced man to be about 8 inches, or approximately 17 inches in all. The drainage of this plot of ground is not good, and we now know that it receives water from the west as sub-irrigation. This we did not know at the beginning of our experiment, or rather we supposed that we were protected from this interference by a ditch and a drain. The water plane during this season was higher than during the succeeding season of 1898, but this, I think, was due in part to greater rainfall and more frequent irrigation. Two factors enter here which are wholly undetermined, the upward movement of the water-soluble salts in the soil, due to evaporation from the surface, and the salts removed by drainage. The former was made as low as our conditions would permit, by keeping the surface soil well stirred by frequent cultivations, and by the luxuriant growth made by the beet tops. I do not know how much either of these agencies accomplished during the season, nor do I know that any attempt has been made to determine the amount of evaporation from the surface of the soil at this place under any conditions. The amount of drainage from this plot was sufficient to lower the water table, after it had been raised by irrigating the plot, two feet in eleven days. In this case, the adjoining land had received no irrigation, and the rise in the water plane was purely local.

§ 46. The draining out of the water may have been due as much to a spreading of the water over a larger area, as to draining out. Under such conditions as the early summer season presented,

the fall of the water plane in this plot took place at the rate of one foot in thirty days. I would have assumed this to be the rate of drainage out of this area, had we not demonstrated, much against our will at the time, that there is a flow of water from the west into our plot, and the fall of one foot in thirty days is simply the excess of the drainage out of the area over that into it.

DEPORTMENT OF SOIL WITH WATER SHRINKAGE INCLUDED.

§ 47. I have stated twice that one characteristic of this soil is its retentiveness of moisture. I do not mean by this statement that it will refuse to give up a larger percentage of moisture than other soils, when exposed to drying out in the air or subjected to drought, but that excessive water is given up slowly, and also that when it dries it shrinks and becomes very hard, which is true of many soils in this State.

§ 48. I made two experiments to determine the rate at which this soil dries after being saturated with water, and also to determine the loss of volume due to shrinkage.

These samples deported themselves very differently. The sample of soil A, placed in a cylindrical box, showed moisture on the surface in seven minutes after the perforated bottom of the box was placed in water, but the soil had not become saturated at the expiration of four and one-quarter hours, and was permitted to stand in contact with the water over night. The sample of soil D, on the other hand, did not show moisture on the surface until forty-five minutes after it was placed in contact with the water, but was saturated in one and one-quarter hours. Soil A required for saturation 18.18 grams of water, and lost in eleven days 17.78 grams; D required 16.62 grams for saturation, and gave up 16.20 grams in eleven days. The shrinkage was the same in both cases, 28 per cent. of the original volume. The cylinders were filled and shaken down to make the soil compact. The loss for each twenty-four hours, up to the end of the seventh day, is given in the following table, together with that for pulverized feldspar, which was used for the sake of comparison. The feldspar had been pulverized so that its particles approached those of the soil as nearly as possible in size. The volumes were the same. It will be born in mind that the soil contains humus, clay, salts, etc., while the feldspar does not. The feldspar showed moisture in one minute after being placed in the water. One sample was saturated in ten and the other in twenty minutes. This is a very pronounced difference, the soils requiring 75 and upwards of 255 minutes for their saturation. The feldspars required for saturation 8.94 and 7.39 grams of water respectively, the soils, 18.18 and 16.60 grams.

TABLE IV.—RATES AT WHICH THE SOILS GAVE UP WATER.

	Soil A. Grams.	Soil D. Grams.	Feldspar. Grams.	Feldspar. Grams.
Water given up in first 24 hrs	3.58	3.10	2.06	2.00
Water given up in second 24 hrs	2.45	3.00	2.52	2.42
Water given up in third 24 hrs	2.47	2.45	1.99	1.95
Water given up in fourth 24 hrs	2.33	2.40	1.85	0.97
Water given up in fifth 24 hrs	2.40	2.40	0.06	0.01
Water given up in sixth 24 hrs	2.10	1.60	....	....
Water given up in seventh 24 hrs	1.20	0.35	....	....

The experiment with the soils was continued for four days longer, but the loss was comparatively slow. The feldspar showed no shrinkage. The temperatures at which these experiments were made were 15°–16° C. for the soil samples, and 16°–17° for the feldspars.

ANALYSES OF HYDROCHLORIC ACID SOLUTIONS OF THE SOILS.

§ 49. The description of these samples has been given in a preceding paragraph, and the method of analysis was a conventional one, digestion with hydrochloric acid, sp. gr. 1.115, on a water bath for five days.

TABLE V.—ANALYSES OF SOILS. GENERAL SAMPLES.

	A. May 13, 1897.	B. May 13, 1897.	C. May 13, 1897.	D. May 13, 1897.	E. May 13, 1897.	F. May 13, 1897.	A. Oct. 20, 1897.	B. Oct. 20, 1897.	C. Oct. 20, 1897.	D. Oct. 20, 1897.	E. Oct. 20, 1897.	F. Oct. 20, 1897.
Insoluble	53.470	70.065	58.951	53.617	62.572	54.262	50.228	70.756	51.047	56.092	61.871	53.572
Silicic Acid, Soluble	17.875	11.379	17.449	18.662	12.918	12.126	21.346	11.587	20.287	17.926	13.552	10.671
Sulfuric Acid	0.827	0.488	0.508	0.921	0.517	0.529	1.433	0.486	0.354	0.927	0.817	0.237
Carbonic Acid	1.208	Trace.	0.652	1.267	2.251	6.934	0.419	Trace.	0.949	0.785	1.991	8.025
Chlorin	0.014	0.014	0.031	0.008	0.033	0.019	0.034	0.019	0.004	0.007	0.007	0.016
Phosphoric Acid	0.112	0.064	0.081	0.061	0.070	0.054	0.086	0.128	0.115	0.099	0.138	0.122
Potash	1.495	1.003	1.443	1.443	0.876	0.854	1.528	0.978	1.457	1.372	0.936	0.750
Soda	0.624	0.521	0.589	0.778	0.610	0.600	0.722	0.540	0.618	0.546	0.535	0.614
Lime	2.479	0.778	1.029	2.751	3.698	9.141	1.944	0.840	1.602	1.777	3.129	10.537
Magnesia	1.649	1.007	1.429	1.446	1.081	1.254	1.697	0.860	1.737	1.353	1.198	1.465
Ferric Oxid	4.075	3.575	4.185	4.225	4.025	3.630	4.320	3.385	4.960	4.170	3.795	3.600
Aluminic Oxid	7.387	4.484	5.587	6.733	4.853	5.190	7.410	4.264	7.281	6.492	4.499	3.756
Manganic Oxid (br)	0.200	0.120	0.140	0.190	0.075	0.065	0.245	0.130	0.290	0.095	0.085	0.190
Moisture at 100° C	3.296	1.765	2.004	2.214	2.020	1.642	2.990	1.526	2.853	2.721	2.109	1.850
Ignition	5.402	3.976	5.581	4.417	5.095	4.103	5.361	4.017	6.035	5.470	5.898	5.223
Sum	100.113	99.246	99.659	99.734	100.694	100.403	99.763	99.516	99.489	99.831	100.460	100.678
Oxygen Equivalent to Chlorin.	0.003	0.003	0.007	0.002	0.008	0.004	0.008	0.004	0.001	0.001	0.002	0.004
Total	100.110	99.243	99.652	99.732	100.686	100.399	99.755	99.512	99.488	99.830	100.458	100.674
Nitrogen	0.0937	0.0882	0.0882	0.0959	0.1295	0.1040	0.0938	0.1022	0.1015	0.1083	0.1191	0.0996
Humus	0.8150	0.9450	0.7360	0.6600	0.8080	0.5740	0.7120	0.9100	0.7400	0.8460	1.0300	0.5020
Phosphoric Acid in Humus.	0.0384	0.0205	0.0296	0.0288	0.0486	0.0384	0.0333	0.0345	0.0396	0.0294	0.0537	0.0334

CONSIDERATION OF ANALYTICAL RESULTS.

§ 50. There is no division of soil into surface and subsoil, except in the case of samples E and F, where E is the soil and F the subsoil. The mechanical and chemical analyses both show that there are marked differences.

The subsoil disappears entirely a few feet east of this point, and is entirely wanting at the point where sample D, the next on the east, was taken. The subsoil contains less decomposable silicates, corresponding to the soluble silicic acid, a considerable quantity of carbonate of lime, and a different mechanical composition.

The surface soils vary more than would be expected, and not in the manner that a knowledge of their physical appearance and deportment under cultivation would lead one to anticipate. Soil A becomes heavily incrusted with alkalies, the incrustation reaching a thickness, at times, of one half inch, while soil E does not at any time show an incrustation and would not be considered as containing any alkali, except for the marked amount of sulfuric acid appearing in the analysis. The carbonic acid in both samples appears to be in combination with calcium to the extent of about 50 per cent. in the case of A, and probably a still greater extent in the case of E. This is the case if the water-soluble portion of the sample represents the salts present in the soil, and no changes are induced by the long treatment with water necessary to remove all the soluble salts. We notice that the sulfuric acid in the samples of A and E, taken in October, is higher than in the samples taken in May. This may be due to a transference of the sulfates from the subsoil to the soil, but taking the two series of samples, we see that only two samples indicate any loss of sulfates, *i. e.*, samples C and F; and as already suggested, the loss in F may account, in part, for the gain in E.

§ 51. The carbonic acid does not give us any strong indication that the season's cropping and cultivation has eliminated much if any alkali from the soil, while the total soda present tends to show that the apparent diminution in the carbonic acid present is to be explained otherwise than by attributing it to any variation of the quantity of alkali. Samples E and D are from contiguous sections. E shows no alkali on the surface, while D shows an abundance of it. If, for the sake of simplicity, we calculate the sulfuric acid as corresponding to sodic sulfate in the soil, we observe that in May it ranges from 0.87 to 1.63 per cent., whereas in October it ranges from 0.63 to 2.54 per cent., one sample only, C, showing a decrease from 0.90 to 0.63 per cent. In the case of the subsoil F, we have a decrease from 0.94 to 0.42 per cent, but in the surface soil E, corresponding to it, we have an increase from 0.92 to 1.45 per cent.

§ 52. This soil E is in excellent condition and would ordinarily be considered free from alkali, but if we calculate the amount of sodic sulfate corresponding to the sulfuric acid in an acre of such soil taken to the depth of one foot, we find in round numbers 16 tons in May, and 25 tons in October. In the subsoil, sample F, we find in May 16 tons and in October 7 tons. It appears that 9 tons of this salt, or its equivalent, has been transferred from the subsoil to the soil by surface evaporation and capillarity, but no incrustation was produced. In the case of sample A, we find a little larger increase in the surface layers, but there is at times a heavy incrustation covering almost the whole of this section. This was not the case at the time the sample was taken. We have a marked change in the other direction in sample C, as we find that about four tons per acre of this salt has passed below the depth to which our sample was taken. It is possible that this salt was washed out or flooded off of this section of the plot at the rate of four tons per acre during the season. I would like to believe this, but I see no reason why I should. The ground here is about one foot higher than at B or D, and the irrigation water flowed towards these points, but there was no increase in the alkali at either B or D. In the case of F there is a patent explanation, in the case of C there is not. The sulfuric acid determinations were done in duplicate in both cases, and agreed within four one hundredths of one per cent. The crop as previously shown did not remove a large amount of sulfuric acid, and I have no explanation for the disappearance of the alkali from this section, unless it was simply carried into the soil by the irrigation and was not brought back by the capillary movement of the water within the reach of our sample. The differences in the percentages of the potash are so small, and the samples not being identical, there is not even the same small object in trying to draw any inferences from them, that there is discussing the effect of the season's work on the "alkali," basing it upon the total amount of sulfuric acid present in the different samples.

One could scarcely expect one season's study and work to produce a change of sufficient magnitude to show a decided difference in the results of such anaylses, nor does the matter stand in a much more favorable relation at the end of three or four years. After three crops had been taken off of the plot, a sample from E showed the presence of 0.849 per cent. of potash, and before any crop had been taken off it showed 0.876 per cent. The plowing, cultivation, irrigation and cropping of three seasons gave us as their total effect this uncertain difference of 0.027 per cent. There were other samples taken, but these are the only two that coincide in the point at which they were taken. Others, however, show the same thing; sample B, for instance, at the beginning showed 1.003 per cent. of potash; after three crops had been taken, we obtained 0.999 per

cent. This shows nothing, because the samples were not taken from points near enough together. The samples of the third season were not taken for the purposes of such a comparison, and merely chance to serve even in this measure. The fact that the nitrogen content in the October samples was higher than in the May samples, has but little if any dependence upon the beet crop, but was possibly very dependent upon the cultivation and irrigation. It is, we may say, a distinct crop, which increases with favorable conditions of season and soil; and our analyses simply show that there was more in the soil on October 20 than on May 13, regardless of what had been removed by the crop or dissolved out by water.

§ 53. The effect upon the organic matter in the soil did not seem to be very decided, but at the end of three seasons there was a gain, not so large, however, as I expected, the tops of two crops of beets and a heavy coating of manure having been added to one half, on alternate sections, of the plot.

§ 54. The analyses, as we ought to expect, do not show us the changes which have really taken place. This plot, for instance, has improved most wonderfully in its quality, and the analyses do not and cannot measure these improvements. It is not a question of composition, but one of conditions.

SOME RESULTS DUE TO THE PRESENCE OF FELDSPAR.

§ 55. The consideration of the mineralogical constituents of the soil renders it evident that in our case we have to deal with the mineral feldspar, and indefinite decomposition products of this mineral, mixed with decaying organic matter. The agricultural analysis of the soil will yield results which will vary with the fineness of the feldspar particles the character of the decomposition products present, with slight variations in manipulation, and with other conditions which one cannot foresee. The minor variations, for instance in the percentages of potash found, as in case of sample A, 1.495 and 1.528, or in B, 1.003 and 0.978, may arise from such causes, and not depend in any way upon cropping or cultivation.

§ 56. As the solubility of feldspar in dilute acids is a well recognized property of this whole class of minerals, the results of the mineralogical study of these samples was somewhat disconcerting, not in regard to the value of such analyses in general, but of my analyses in particular. The abundance of this mineral present, the abundance of potash soluble in dilute acid, and the impossibility of washing out all the lime, soluble in dilute hydrochloric acid in any reasonable time, led me to experiment with orthoclase, powered so fine that the whole mass would pass through a sieve with one millimeter mesh, because this is the conventional size of the particles of fine earth. Thirty-three per cent. of

this was less than one quarter of a millimeter in diameter. The mechanical analyses of the soils show that 60 per cent. of the soil particles are smaller than one fourth of a millimeter in diameter. This feldspar used had been washed out of the soil and was treated just as the soil was, and the results were as follows: Potash dissolved out of the feldspar by digesting with hydrochloric acid, sp. gr. 1.115, for five days, was 0.845 per cent.; soda, 0.816 per cent.; silicic acid set free, 4.31 per cent. This simple experiment is so decisive of the fact that five days digestion with dilute hydrochloric acid, sp. gr. 1.115, will extract potash from finely divided orthoclase in considerable quantities, that further questions arise as to whether plants can use the potash present in this form, or is our analysis of such a soil wholly misleading? The following questions are also suggested, viz: To what extent does water alone act on this mineral, for that water extracts potash from it is already an established fact, and how much does carbonic acid increase its solvent action?

ACTION OF WATER AND CARBONIC ACID ON FELDSPAR.

§ 57. The perfectly fresh, finely pulverized feldspar was suspended in water, 10 grams in 300 c. c., and allowed to stand five days with frequent shaking. One hundred c. c. of this solution was filtered off, evaporated to dryness, and the residue weighed. Another portion of feldspar was treated in the same manner, except that the water was saturated with carbonic oxid.

§ 58. A like quantity of water was placed beside these and carried through as a control.

§ 59. The water dissolved from the feldspar 0.0081 gram, after deducting the amount contained in the distilled water.

§ 60. The water charged with carbonic oxid dissolved 0.0723 gram. The residue obtained in this case gave a heavy precipitate for potash with platinic chlorid, as did the water solution of the feldspar. The residue from the distilled water did not react for potash.

EXPERIMENTS WITH OATS.

§ 61. This question was carried still further, and we endeavored to determine whether the feldspar could furnish potash to plants. For this purpose the perfectly fresh mineral was used, pulverized as already described in imitation of the soil, *i. e.*, the particles varied from one millimeter in diameter to an impalpable powder. This was mixed with pure quartz sand. Bone ash was used to supply lime and phosphoric acid. The sample used contained no potash. Nitrate of lime furnished the nitrogen. Chlorin was furnished by a minute quantity of calcic chloride. Distilled water was used throughout the experiment.

The plants grew healthily in this mixture until the floors of the

building were oiled and the room in which the plants were growing was shut up and became too warm; these two things together gave them a decided set back, and later a thrips, *Thrips striata*, according to Prof. Gillette, attacked the plants and did them much damage. Some of the plants, however, seeded. They were harvested, though in bad condition and very uneven in the degree of their development. The root system was well developed, the sand being filled with the roots. The weight of the tops as harvested was 198.5 grams; that of the roots as washed out was 40 grams. The tops and roots were incenerated together and yielded 5.795 per cent. of soluble and 9.803 per cent. of insoluble ash, a total of 15.598 per cent.

§ 62. Examination of the feldspar used showed the presence of 11.993 per cent. of potash, and 2.988 per cent. of soda. Phosphoric and sulfuric acids were present in very small quantities, the former equalled 0.041 per cent. and the latter 0.003 per cent. of the feldspar.

§ 63. The nitrogen in the oat hay, roots included, was 3.2543 per cent.

The ash gave the following analysis:

TABLE VI.—ANALYSIS OF OAT ASH GROWN WITH FELDSPAR.

	Per Cent
Carbon	0.172
Sand	8.135
Silicic Acid	15.737
Sulfuric Acid	4.411
Phosphoric Acid	3.982
Carbonic Acid	15.356
Chlorin	2.732
Potassic Oxid	15.959
Sodic Oxid	4.622
Calcic Oxid	21.709
Magnesic Oxid	3.906
Ferric Oxid	0.696
Aluminic Oxid	0.314
Manganic Oxid	0.163
Ignition	2.611
Sum	100.505
Oxygen Equivalent to Chlorin	0.615
Total	99 890

RESULTS SHOWN BY EXPERIMENT WITH FELDSPAR.

§ 64. This ash is very anomalous in its composition as well as in the quantity present in the plants. The plants were not evenly mature at the time of gathering and were in bad condition. The question we endeavored to investigate, however, is perfectly answered by the results, *i. e.*, the oat plant can use the finely divided feldspar as a source from which to obtain potash; for in this experiment, made under very adverse conditions, we find that the oat plants

took from the feldspar 1.4417 grams of potash. The potash added in the seed has been deducted. The silicic acid appropriated by the plant indicates the decomposition of the silicate. The partially decomposed, finely comminuted feldspar is actually a part of the soil. Its deportment toward water, especially when charged with carbonic oxid, is also strongly suggestive of this conclusion.

§ 65. This fact is of very general importance, as it applies to so large a portion of our soils; it also facilitates the interpretation of our analytical data, and enhances their value a little. The mass analyses show that our soils contain from 2.24 to 2.50 per cent. of potash—the latter seems to be the rule, about 2.50 per cent. The agricultural analysis of samples from all parts of the State show a range from 0.10 to 1.50 per cent. In fifty-eight analyses of samples from different counties of the State, only five fall so low as 0.15, and very few of the rest so low as 0.25 per cent. It is evident that, so far as the results of analyses are reliable, the soil with which we have been experimenting is richer in this constituent than the average soil. This is, I believe, true of all of alkali land.

ANALYSIS OF THE ACID SOLUBLE AND INSOLUBLE PORTION OF SOIL A.

§ 66. The mineralogical composition of our soil, *i. e.*, quartz and feldspar, and the decomposition products of the latter, together with the results of our experiments with feldspar, suggest the combination of the mass analysis and agricultural analysis to give us some idea of the relation of the agricultural analysis to the actual composition of the soil. We, therefore, in order to exhibit as fully as we can the chemical composition of this soil, give the agricultural analysis of soil A, together with the analysis of the residue designated as insoluble in the agricultural analysis.

TABLE VII.—ANALYSES OF THE ACID SOLUBLE AND INSOLUBLE PORTION OF SOIL A.

	Soluble in HCl., sp. gr. 1.115, 5 days digestion. Per cent.	*Insoluble in HCl., sp. gr. 1.115, 5 days digestion. Per cent.*
Silicic Acid	17.875	46.870
Sulfuric Acid	0.827	None
Carbonic Acid	1.208	......
Chlorin	0.014	......
Phosphoric Acid	0.112	None
Potash	1.495	0.800
Soda	0.624	0.560
Lime	2.479	0.310
Magnesia	1.649	0.170
Ferric Oxid	4.075	0.400
Aluminic Oxid	7.387	4.330
Manganic Oxid	0.200	Trace
Moisture at 100° C	3.296	......
Ignition	5.402	......
	46.640	53.440
Total		100.080

DISCUSSION OF ANALYSIS.

§ 67. This analysis shows that 65 per cent. of the potash, 63 per cent. of the alumina, 90 per cent. of the oxid of iron, 27.6 per cent of the silicic acid, a very high percentage of the lime and magnesia, and the whole of the sulfuric and phosphoric acids, were removed or, as in the case of the silicic acid, rendered soluble in sodic carbonate. If the silicic acid rendered soluble by this treatment be taken as the measure, then the action of the hydrochloric acid on the soil was between six and seven times as great as it was on pure feldspar, and probably not more than one sixth of the silicic acid could come from the decomposition of this mineral. The potash dissolved out of the soil is about 75 per cent. greater than was taken into solution from the pure, fresh mineral. The relative amount of soda dissolved out of the feldspar was high compared with the amount of potash dissolved, but low when compared with the percentage of soda dissolved out of the soil. A glance at the analysis shows that, taken roughly, 50 per cent. of the soda in the soil was dissolved out, but only about 25 per cent. of it went into solution in the case of the feldspar. The relatively large amount of soda dissolved out of the feldspar by digestion with the dilute hydrochloric acid, is probably due to the fact that the feldspar used was not wholly composed of the potash feldspar, orthoclase, but may have contained an admixture of oligoclase, another feldspar, rich in soda and more readily attacked by acids. When we take up the portion of the soil soluble in water we shall see that some, as much perhaps as one third, of the soda is present in a form readily soluble in this menstruum, and in this case belongs to the "alkalis" present.

THE WATER-SOLUBLE IN THE SOIL.

§ 68. When these soils are treated with fresh portions of water, so long as they yield either chlorin or sulfuric acid to the water and the amount taken into solution is determined, we find it ranging from 0.389 per cent. to 2.550 per cent. Soil A yielded the highest amount to water, 2.55 per cent., taking the sample to a depth of ten inches, and as high as 3.93 per cent. taking the first two inches of the soil.

§ 69. In stating the analyses of the portions of different samples soluble in water, I have combined the acids and bases and give the salts alongside of the direct analytical results. The order followed in combining them will be apparent to anyone upon an inspection of an analysis. I have adopted this order and have been as uniform as possible throughout. This order is convenient and probably represents the salts present in the soil as nearly as any other which might have been adopted, but it is certainly not always correct.

§ 70. The water-soluble has been determined in one set of general samples, but has been analyzed in only one case, that of sample B, taken in 1897. The analysis is not wholly satisfactory, showing too large an excess of sodic oxid, even after using all of the silicic acid present. A large quantity of organic matter in an analysis is sometimes accompanied by an excess of soda. This analysis was made on a smaller amount of material than the analyst was accustomed to, and other conditions did not contribute either to his comfort or to the accuracy of his work. The water-soluble amounted in this instance to 0.878 per cent. of the soil.

TABLE VIII.—ANALYSIS OF THE WATER-SOLUBLE IN SAMPLE B, 1897.

	Per cent.
Silicic Acid	1.516
Sulfuric Acid	50.451
Carbonic Acid	0.140
Chlorin	1.529
Sodic Oxid	14.423
Potassic Oxid	2.517
Calcic Oxid	15.091
Magnesic Oxid	7.608
Aluminic and Ferric Oxids	0.152
Manganic Oxid (br)	not det.
Ignition	6.885
Sum	100.312
Oxygen Equivalent to Chlorin	0.344
Total	99.968

Combined.	Per cent.
Calcic Sulfate	36.633
Magnesic Sulfate	22.824
Potassic Sulfate	4.659
Sodic Sulfate	20.513
Sodic Chlorid	2.523
Sodic Carbonate	0.337
Sodic Silicate	3.078
Aluminic and Ferric Oxids	0.152
Manganic Oxid	not det.
Ignition	6.885
Sum	97.604
Excess of Soda	2.400
Total	100.004

§ 71. Analysis shows that the whole of the sulfuric acid in these soils is soluble in water and in hydrochloric acid. The soil analysis of B, sample taken May 13, was made on the same sample that was extracted with water and the analysis of which extract is given above. The difference when the sulfuric acid is calculated into percentage of the soil is far within the limit of the analytical errors, being only 0.045 per cent. In regard to the order in which the acids and bases have been combined, it appears that there is but little choice. The water-soluble consists essentially of sulfates. The above residue was obtained by washing the soil so long as the water with which it was digested in the cold for twenty-four hours showed any trace of sulfuric acid. The water used in the particular case given, sample B, was not measured, but it was in all of the cases to be given and ranged from 18 to 45.5 litres per 1,000 grams of the soil.

THE WATER-SOLUBLE PORTION OF THE SOIL DIFFERENT FROM THE INCRUSTATION.

§ 72. It may be well to anticipate a later discussion to the extent of stating that the water-soluble in the soil is not the same, as the "alkali" that effloresces from the soil. The salts are of the same

kind, sulfates, but while the predominant soluble salt in the soil is calcic sulfate, that in the alkali which effloresces from this ground is sodic sulfate, with magnesic sulfate second in quantity, while the calcic sulfates is but little greater than the sodic chlorid.

§ 73. The analysis is not unsupported in showing a large amount of calcic sulfate to be present. I caused several boxes of the soil to be gathered and planted with beet seed. These boxes were covered with glass and left standing for some days. When they were examined again there was an abundant crop of fine acicular crystals of gypsum uniformly distributed over the surface. Inspection of the soil as it was turned up by the plow also showed this substance to be present. Its abundance suggested the possibility of this soil having sometime received a heavy dressing of gypsum, in the hope of correcting the evil of the alkali, but I could not learn that such had been the case, and the presence of the gypsum in its present quantity seems to be due to accumulation of this salt from the evaporation of the ground water.

WATER-SOLUBLE PORTION OF THE SOIL DIFFERENT FROM SALTS IN GROUND WATER.

§ 74. The salts held in solution by the ground water agree more nearly with the water soluble in the soil than those which effloresce and are considered as alkali, but even the ground waters are not solutions of the water soluble portion in the soil. They differ in two essentials, in the amount of silicic acid and also in that of potash, which they contain. The water-soluble portion of the soils being richer in these constituents, sometimes containing ten times as much of one or the other of these. The water-soluble in the soil, on the other hand, is not at all uniform in its relative content of sodic sulfate, and is oftener poor in this salt than even mediumly rich. In only two cases out of the eight following analyses does it constitute any considerable fraction of the water-soluble salts, and in these cases its presence in such large quantity, 17.7 and 27.2 per cent. of the soluble salts, is probably due to its concentration at the surface and its subsequent washing back into the soil, as the samples represented the first two inches of the soil from sections where efflorescences are always formed under favorable conditions. The fact that the water-soluble salts are richer in potash than the soil water is explicable by the facts which have been demonstrated, by the action of water on the feldspar and the property of certain compounds in the soil of exchanging lime for potash brought into contact with them through the agency of solutions, the ground water being in this manner deprived of its potash, receiving lime in exchange. The analyses of the parts of the soil classified according to the size of their grains showed an increasing percentage of potash as the grains of the respective parts became

finer, until it reached its maximum in the dust and clay. The continued treatment with pure water, used in small portions at a time, yet relatively large compared with that acting upon the same amount of soil in the field, may act more energetically upon the feldspar than the soil waters do, but in considering this the presence of carbonic acid in the soil is not to be neglected, as it strongly tends to increase the solvent action of water upon this mineral.

§ 75. The analyses of the water-soluble portion of these soils show, as a rule, very much more silicic acid than is present in the residues from the ground waters. This fact, together with the higher percentage of potash which the water-soluble portions uniformly contain, suggest that the reaction itself is either primarily different or that there is a subsequent reaction between the ground water solution and the soil. The known ability of soils to remove potash from solutions seems to make it probable that such secondary reaction takes place. The more exact nature of this reaction is not known. I believe, however, that such a reaction would account very largely, if not wholly, for the accumulation of the potash in the very fine portions of the soil, among which these newly formed and highly reactive compounds are included.

THE WATER-SOLUBLE PORTION OF THE SOIL.

§ 76. The following tables exhibit the composition of the water-soluble portions of the first and second two inches of the soil. They give us an idea of the differences which exist in the salts of the different layers of the soil, but no correct idea of the distribution of the alkali, for the samples were taken on different dates.

That which has already been said in regard to the order in which the acids and bases, oxids, have been combined probably needs to be emphasized. The order adopted seems to be the most convenient one for the majority of cases, and approximates the facts in these cases, but is not always correct. Phosphoric acid, when found in these residues, has been combined with magnesia. While this may be correct, it is more probable that it was in combination with lime. Its quantity, however, is so small that no great violence is done to our knowledge or to the facts.

TABLE IX.—WATER-SOLUBLE, SOIL A, FIRST TWO INCHES.

	Per cent.
Silicic Acid	0.574
Sulfuric Acid	49.411
Phosphoric Acid	None
Carbonic Acid	0.721
Chlorin	5.557
Potassic Oxid	1.223
Sodic Oxid	14.301
Calcic Oxid	16.189
Magnesic Oxid	7.635
Aluminic and Ferric Oxids	Trace
Manganic Oxid	0.297
Ignition	5.058
Sum	100.966
Oxygen Equivalent to Chlorin	1.252
Total	99.714

Combined.	*Per cent.*
Calcic Sulfate	39.289
Magnesic Sulfate	22 924
Potassic Sulfate	2.263
Sodic Sulfate	17.728
Sodic Chlorid	9.167
Sodic Carbonate	1.737
Sodic Silicate	1.165
Aluminic and Ferric Oxids	Trace
Manganic Oxid	0.297
Ignition	5.058
Sum	99.628
Excess of Sodic Oxid	0.081
Total	99.709

The percentage of water-soluble equalled 3.93.

TABLE X.—WATER-SOLUBLE, SOIL A, SECOND TWO INCHES.

	Per cent.
Silicic Acid	1.999
Sulfuric Acid	51.740
Phosphoric Acid	0.129
Carbonic Acid	3.092
Chlorin	0.939
Potassic Oxid	1.490
Sodic Oxid	4.429
Calcic Oxid	26.617
Magnesic Oxid	7.591
Aluminic and Ferric Oxids	0.161
Manganic Oxid	0.209
Ignition	2.173
Sum	100.569
Oxygen Equivalent to Chlorin	0.212
Total	100.357

Combined.	*Per cent.*
Calcic Sulfate	64.594
Magnesic Sulfate	20.642
Magnesic Phosphate	0 229
Magnesic Carbonate	1.285
Potassic Carbonate	2.185
Sodic Carbonate	4.157
Sodic Chlorid	1.549
Sodic Silicate	2.312
Aluminic and Ferric Oxids	0.161
Manganic Oxid	0.209
Ignition	2.173
Sum	99.496
Excess of Silicic Acid	0.861
Total	100.357

The percentage of water-soluble equalled 2.55.

TABLE XI.—WATER-SOLUBLE, SOIL B, FIRST TWO INCHES.

	Per cent.
Silicic Acid	1.348
Sulfuric Acid	47.649
Phosphoric Acid	None
Carbonic Acid	1.311
Chlorin	4.008
Potassic Oxid	2.048
Sodic Oxid	18.632
Calcic Oxid	13.900
Magnesic Oxid	5.365
Aluminic and Ferric Oxids	0.113
Manganic Oxid	0.266
Ignition	6.281
Sum	100.921
Oxygen Equivalent to Chlorin	0.903
Total	100.018

Combined.	*Per cent.*
Calcic Sulfate	33.733
Magnesic Sulfate	16.108
Potassic Sulfate	3.789
Sodic Sulfate	27.229
Sodic Chlorid	6.612
Sodic Carbonate	3.158
Sodic Silicate	2.714
Aluminic and Ferric Oxids	0.113
Manganic Oxid	0.266
Ignition	6.281
Sum	100.003
Excess of Silicic Acid	0.012
Total	100.015

The percentage of the water-soluble equalled 0.75.

TABLE XII.—WATER-SOLUBLE, SOIL B, SECOND TWO INCHES.

	Per cent.
Silicic Acid	6.768
Sulfuric Acid	40.378
Phosphoric Acid	0.407
Carbonic Acid	4.738
Chlorin	2.821
Potassic Oxid	2.042
Sodic Oxid	9.826
Calcic Oxid	19.165
Magnesic Oxid	6.954
Aluminic and Ferric Oxids	0.390
Manganic Oxid	0.760
Ignition	[6.387]
Sum	100.636
Oxygen Equivalent to Chlorin	0.636
Total	100.000

Combined.	Per cent.
Calcic Sulfate	46.510
Magnesic Sulfate	16.939
Magnesic Phosphate	0.751
Magnesic Chlorid	2.296
Potassic Sulfate	3.778
Sodic Chlorid	1.825
Sodic Carbonate	11.414
Sodic Silicate	4.295
Aluminic and Ferric Oxids	0.390
Manganic Oxid	0.760
Ignition	[6.387]
Sum	95.345
Excess of Silicic Acid	4.654
Total	99.999

The percentage of water-soluble equalled 0.389.

TABLE XIII.—WATER-SOLUBLE, SOIL C, FIRST TWO INCHES.

	Per cent.
Silicic Acid	1.084
Sulfuric Acid	48.826
Phosphoric Acid	None
Carbonic Acid	0.385
Chlorin	4.321
Potassic Oxid	1.338
Sodic Oxid	10.190
Calcic Oxid	17.826
Magnesic Oxid	8.080
Aluminic and Ferric Oxids	——
Manganic Oxid	0.342
Ignition	8.281
Sum	100.673
Oxygen Equivalent to Chlorin	0.973
Total	99.700

Combined.	Per cent.
Calcic Sulfate	43.260
Magnesic Sulfate	24.260
Potassic Sulfate	2.475
Sodic Sulfate	10.789
Sodic Chlorid	7.128
Sodic Carbonate	0.928
Sodic Silicate	2.202
Aluminic and Ferric Oxids	–
Manganic Oxid	0.342
Ignition	8.281
Sum	99.665
Excess of Sodic Oxid	0.031
Total	99.696

The percentage of water-soluble equalled 2.0544.

TABLE XIV.—WATER-SOLUBLE, SOIL C, SECOND TWO INCHES.

	Per cent.
Silicic Acid	9.095
Sulfuric Acid	34.832
Phosphoric Acid	0.522
Carbonic Acid	5.558
Chlorin	2.663
Potassic Oxid	3.252
Sodic Oxid	8.778
Calcic Oxid	20.981
Magnesic Oxid	7.131
Aluminic and Ferric Oxids	0.878
Manganic Oxid	0.245
Ignition	6.996
Sum	100.951
Oxygen Equivalent to Chlorin	0.600
Total	100.351

Combined.	Per cent.
Calcic Sulfate	50.917
Magnesic Sulfate	3.197
Potassic Sulfate	6.016
Magnesic Phosphate	0.963
Magnesic Chlorid	3.565
Magnesic Carbonate	8.646
Sodic Carbonate	2.490
Sodic Silicate	14.418
Aluminic and Ferric Oxids	0.898
Manganic Oxid	0.245
Ignition	6.996
Sum	98.351
Excess of Silicic Acid	1.998
Total	100.349

The percentage of water-soluble equalled 0.813.

TABLE XV.—WATER-SOLUBLE, SOIL D, FIRST TWO INCHES.

	Per cent.
Silicic Acid	2.261
Sulfuric Acid	48.354
Phosphoric Acid	———
Carbonic Acid	0.768
Chlorin	2.670
Potassic Oxid	3.792
Sodic Oxid	5.604
Calcic Oxid	22.084
Magnesic Oxid	5.486
Aluminic and Ferric Oxids	0.011
Manganic Oxid	0.662
Ignition	8.789
Sum	100.477
Oxygen Equivalent to Chlorin	0.602
Total	99.875

Combined.	Per cent.
Calcic Sulfate	53.593
Magnesic Sulfate	16.473
Potassic Sulfate	7.015
Sodic Sulfate	4.682
Sodic Chlorid	4.405
Sodic Carbonate	1.841
Sodic Silicate	0.282
Aluminic and Ferric Oxids	0.011
Manganic Oxid	0.662
Ignition	8.789
Sum	97.753
Excess of Silicic Acid	2.122
Total	99.875

The percentage of water-soluble equalled 0.800.

TABLE XVI.—WATER-SOLUBLE, SOIL D, SECOND TWO INCHES.

	Per cent.
Silicic Acid	3.354
Sulfuric Acid	44.392
Phosphoric Acid	Trace
Carbonic Acid	5.738
Chlorin	0.632
Potassic Oxid	1.310
Sodic Oxid	5.594
Calcic Oxid	27.656
Magnesic Oxid	5.895
Aluminic and Ferric Oxids	0.443
Manganic Oxid	0.227
Ignition	4.919
Sum	100.160
Oxygen Equivalent to Chlorin	0.142
Total	100.018

Combined.	Per cent.
Calcic Sulfate	67.116
Magnesic Sulfate	7.397
Magnesic Carbonate	7.202
Potassic Carbonate	1.922
Sodic Chlorid	1.042
Sodic Carbonate	3.265
Sodic Silicate	6.164
Aluminic and Ferric Oxids	0.443
Manganic Oxid	0.227
Ignition	4.919
Sum	99.697
Excess of Silicic Acid	0.321
Total	100.018

The percentage of water-soluble equalled 0.864.

§ 77. The quantity of water used in extracting the soils ranged from 18 to 45.5 litres, and the time of extracting from 14 to 68 days. It was thought that the long time and large quantities of water used might have made some differences in the results which a quick extraction would make evident, but two experiments made on quantities of 10 and 150 grams each failed to show anything of sufficient interest to lead us to prosecute the work. The silicic acid, sulfuric acid, lime and magnesia extracted from 10 grams in from 30 to 45 minutes differed but a few hundredths of a per cent., when calculated on the soil used, from the figures obtained in the more carefully prepared extract. In the experiment with 150 grams the alkalies and magnesia with the silicic acid went into solution more readily than the last portions of lime and sulfuric acid. This is entirely in accordance with the properties of these

sulfates, but tends to show that the silicic acid is present as easily soluble silicates, probably as an alkaline silicate.

THE DISTRIBUTION OF THE SALTS IN THE FIRST AND SECOND TWO INCHES OF THE SOIL.

§ 78. I regret exceedingly that these sets of samples were not taken on the same date, but the record shows them to have been taken nearly a year apart. The set representing the first two inches having been taken in June, 1899, and that representing the second two inches in May, 1900. The two series are not comparable, except in a very general way, but the members of the series are perfectly so among themselves. The larger features of their differsnces are probably thoroughly representative of the facts, and show that the first two inches of the soil contains a somewhat higher percentage of soluble salts than the second two inches; that the sodic and magnesic sulfates constitute a materially higher percentage of these salts than they do in the second two inches; that the first two yielded less silicic acid than the second two inches; that the potassic oxid soluble in water is very irregular, but is present in both series in significant quantities; that there is no soluble phosphorie acid in the series representing the first two inches, and is present throughout that representing the second two inches. I was at first inclined to think that this was an error, but it is not. The plots from which these samples were taken had been cultivated, but had not received any manure.

§ 79. The uniformity of the presence of phosphoric acid as well as the significant quantity in which it is present is a matter of some surprise. Phosphoric acid is sometimes present in drainage waters in appreciable quantities, but usually only in traces. I have repeatedly tested the residues obtained by evaporating the ground waters of this plot for phosphoric acid, but I have not been able to prove the presence of a trace of it.

In regard to the silicic acid, a trifling amount of it might have been derived from the glass by solution, aided by the repeated shaking of the mass in the bottles, but the solutions made quickly, using freshly distilled water, gave the same results.

THE ALKALI.

§ 80. The efflorescence which forms on the surface of the soil is popularly called alkali, and is of common occurrence in many places in all parts of the State. It is not my intention to go into this subject at present, except as it pertains to this particular soil.

§ 81. There are small areas almost everywhere, especially in irrigated sections, which at times are white with a crop of these salts. They are not sightly from the agriculturists' standpoint, but are much less injurious in themselves than the conditions which admit of their formation. We have seen that among the salts

present in the soil are sodic, magnesic and calcic sulfates, and sodic chlorid. This is not the order, according to the respective quantities in which they occur in the soil, but in the incrustation formed on the top of the soil. There is an order, seemingly, in which the salts come to the surface or are brought there by capillary action, the sodic and magnesic sulfates forming some 80 per cent. of the total salts brought to the surface and deposited from the solutions in this soil. The character of these deposits, these alkalies, will vary in different localities. This variation undoubtedly depends upon the nature of the solutions in the soil, *i. e.*, the salts present in the ground water, rather than upon the nature of the water extract which we may be able to make of the soil. The salts present in the ground waters are intermediate in the order of their relative quantities between the water-soluble in the soil and the alkali incrustation, but are of the same kind. The analyses already given of the water-soluble salts, and those given in the following tables, represent the extremes for our soil.

TABLE XVII.—ANALYSIS OF ALKALI FROM SOIL A, JUNE 23, 1897.

	Per cent.
Silicic Acid	0.282
Sulfuric Acid	53.637
Carbonic Acid	0.513
Chlorin	2.103
Potassic Oxid	0.520
Sodic Oxid	28.259
Calcic Oxid	3.097
Magnesic Oxid	9.136
Aluminic and Ferric Oxids	0.090
Manganic Oxid	0.117
Ignition	3.112
Sum	100.596
Oxygen Equivalent to Chlorin	0.474
Total	100.122

Combined.	*Per cent.*
Calcic Sulfate	7.518
Magnesic Sulfate	27.408
Potassic Sulfate	0.963
Sodic Sulfate	53.682
Sodic Chlorid	3.470
Sodic Carbonate	1.237
Sodic Silicate	0.572
Aluminic and Ferric Oxids	0.090
Manganic Oxid	0.117
Ignition	3.112
Sum	98.168
Excess of Sodic Oxid	1.954
Total	100.123

TABLE XVIII.—ANALYSIS OF ALKALI FROM SOIL A, JULY 5, 1897.

	Per cent.
Silicic Acid	0.129
Sulfuric Acid	52.127
Carbonic Acid	0.488
Chlorin	5.574
Potassic Oxid	0.315
Sodic Oxid	29 785
Calcic Oxid	1.369
Magnesic Oxid	9.684
Aluminic and Ferric Oxids	0.111
Manganic Oxid	0.101
Ignition	1.571
Sum	101.254
Oxygen Equivalent to Chlorin	1.256
Total	99.998

Combined.	*Per cent.*
Calcic Sulfate	3.323
Magnesic Sulfate	29.059
Potassic Sulfate	0.580
Sodic Sulfate	54.217
Sodic Chlorid	9.198
Sodic Carbonate	1.177
Sodic Silicate	0.262
Aluminic and Ferric Oxids	0.111
Manganic Oxid	0.101
Ignition	1.571
Sum	99.601
Excess of Sodic Oxid	0.396
Total	99.997

These analyses are sufficient to show how very different the percentages of the various salts are in the alkali, and in that portion of the soil which is soluble in water. The latter contains a relatively small amount of sodic sulfate, the former a large amount. The sodic sulfate, together with the magnesic sulfate, is concentrated in the alkali.

FORMATION OF ALKALI INCRUSTATIONS EXPLAINED.

§ 82. The formation of these incrustations effects a rough separation of the markedly efflorescent salts, sodic and magnesic sulfates, from the permanent calcic sulfate. Ordinary salt, sodic chlorid, which is present, is also concentrated in the alkali, but not nearly to a like extent, as those already named. The highest figure obtained for the sodic sulfate in any sample of the water-soluble is in the first two inches of soil designated as B, in which it amounts to 27 per cent. In the alkalies it is practically 54 per cent., or twice as much. The highest percentage of magnesic sulfate in the water-soluble is 24 per cent., found in the first two inches of the soil C, while the average for the two samples of alkali is 28 per cent. The decrease of the calcic sulfate from the amount present in the water-soluble to that present in the alkali, is more marked than the increase in the sodic sulfate in the alkali given above. The minimum of the calcic salt found in the water-soluble is 34 per cent., the maximum 67 per cent., while the amount in these alkalies are 7.5 and 3.3 per cent., respectively. These relations show us the deportment of these salts when present in the soil solutions, whose surfaces are brought up and exposed to the evaporating influences of the atmosphere and sun. It is quite a different matter when the free surface of the water in lakes and ponds is presented to the same. In this case there is simply an evaporation to dryness, and the residue represents the salts held in solution by the waters, whereas, in the efflorescing alkalies we have the chemical and physical properties of these salts playing an important, if not the most important part. The sodic sulfate is predominant in the alkali, not because there is more of it in solution in the soil, but because it is separated more readily at the surface of the solution than the calcic sulfate. Magnesic sulfate also passes out of the solution more readily than the calcic sulfate, not because there is more of it in the solution, but because its chemical properties are different and its department toward the dissolving water and the soil particles is different. This subject will be discussed more fully and facts given, when we consider the soil waters. I wish, however, to emphasize the fact that the efflorescent alkalies are quite different from the residues left by evaporating bodies of water; such residues seem to be intermediate between those obtained by evaporating ground waters to dryness and the salt brought to the surface by capillarity and separated as efflorescences on the ground.

ALKALINITY OF THIS SOIL.

§ 83. Several attempts were made to estimate the alkalinity of the soil, but without satisfactory results. It was simply determined that they all reacted with cochineal and a properly prepared litmus solution, showing an alkaline reaction. This reaction was more decided when the moistened soil was placed on litmus paper and allowed to remain there for a few minutes. While the samples were all alkaline, none of them were strongly enough so to permit of its determination by a one hundredth normal acid solution. I was not at all satisfied as to the cause of the alkaline reaction, for the samples of soil which had been washed free from the sulfates still showed the reaction when placed on litmus paper.

FREE AMMONIA IN THE SOIL.

§ 84. Though aware of the unsatisfactory results obtained in endeavors to make this determination, I thought that the peculiar character of our soil and the very frequent occurrence of similar soils in Colorado, would justify me in making the attempt.

§ 85. The samples were taken in their fresh condition, magnesic oxid added, and after standing a short time, an hour or so, were subjected to distillation. Ammonia-free-water was used throughout this experiment. The disillate at first was rich in ammonia, and while it became poorer and poorer, it continued to give a decided reaction with Nessler's reagent for ten days, when the experiment was stopped. It the case of sample No. 3, the whole of the ammonia was given off in four days. Three samples, Nos. 1 and 3 from plots which had not received any manure, and No. 2 from a manured plot, were subjected to distillation. The results obtained were:

No. 1. Ammonia in dry soil----0.00962 per cent.
No. 2. Ammonia in dry soil----0.00765 per cent.
No. 3. Ammonia in dry soil----0.00367 per cent.

The persistency with which the ammonia continued to come over, showed that it was probably being formed during the distillation and was not originally present as free ammonia, or as ready formed ammonia salts. In order to obtain as much evidence as possible regarding the occurrence of free ammonia in this soil, a fresh portion of sample No. 1, was taken and subjected to distillation with the addition of ammonia-free-water alone. The distillation was, as in the previous cases, permitted to proceed very slowly until two and a half litres of distillate were collected. There were still traces of ammonia coming over. The ammonia obtained equalled 0.00211 per cent. of the dry soil. The comparatively abundant evolution of ammonia in the early stages of the distillation with magnesic oxid, and the decided quantity yielded upon

distillation with pure water, prove the presence of both ammonical salts and free ammonia in this soil, and the samples show that the amount of them was not dependent upon the manure added to the soil one year previous to the time that they were taken. I interpret the formation of ammonia salts and free ammonia in this soil, as indicating unfavorable biological conditions. The sample numbered 1 in this series is from that section of the plot which I have described elsewhere as a paludal soil. Its reclamation was not at this time complete. I may be mistaken in this view, but I believe it to be the explanation, and that the larger quantity of ammonical salts and free ammonia were due to the greater resistance this soil had presented to the ameliorating effects of cultivation.

§ 86. The examinations made of the ground waters, not only strengthen but extend this view. The ground waters show not only ammonia, but large amounts of nitrites, indicating a probable reduction of nitrates in some zone of the soil. The presence of ammonia in the upper portions of the soil is probably the most suspicious of all of our facts, as it seems to indicate a slow oxidation, and brings the zone of denitrification to the very surface.

VOLATILE ACIDS IN THE SOIL.

§ 87. The conditions obtaining in this soil being such that acid fermentations might take place, an attempt was made to determine the quantity of such acids, if any were present. Two samples of soils were examined for volatile acids; one had received manure and the other had not. The sample which had received manure yielded volatile acids, other than hydrochloric, equal to 1.3 c. c. of one hundredth normal soda solution. The one which had not received manure yielded volatile acids corresponding to 10.30 c. c. of the soda solution. These are exceedingly minute quantities and their only possible value is a qualitative one, suggesting that one of the effects of the manure added was to lessen the amount of these acids in the soil by modifying the character of the changes taking place within the soil.

NITROGEN AND NITRATES IN THE SOIL.

§ 88. Less has been done with this subject than appears desirable. My excuse is, that I have tried to study this subject in connection with the ground water, rather than with the soil, because there is no material and permanent accumulation of the nitrates in the soil, where it receives water enough, either as rainfall or as irrigation, to remove them more or less nearly at the same rate at which they are formed in the soil.

§ 89. The samples in which the total nitrogen was determined are comparable in a general way only, owing to the fact that the

soil is very varying, and that the samples were not taken from the same places in the plot. This variability in the soil is shown with greatest certainty in the amounts of potash in the different samples, these amounts varying much more than can justly be attributed to analytical errors. The series of samples in which I have made such determinations may serve as a measure of the changes which the cultivation of this soil had effected in the time elapsing between the taking of the samples The nitrogen determinations for the year 1897 have not been taken from the table of "Analyses of Soils, General Samples," but were made on special samples. The samples for 1899 are sufficiently described as manured and not manured, the manure having been applied in 1898, one year before the samples were taken.

TABLE XIX.—TOTAL NITROGEN IN THE SOIL.

1897.	*Per cent.*	*1899.*	*Per cent.*
Sample A	0.0920	No. 3, not manured	0.0935
Sample B	0.0945	No. 3, manured	1.1700
Sample C	0.0829	No. 2, not manured	0.1355
Sample D	0.0819	No. 2, manured	0.1295
Sample E	0.1382	No. 1. not manured	0.1316
Sample F*	0.1081	No. 1, manured	0.1312

§ 90. The samples have been arranged in this table so that those representing the same general sections stand as nearly opposite each other as possible, but they are not identical.

§ 91. The samples were taken in the same month of the year, and, so far as seasonal influences upon the nitrogen content are concerned, are comparable. The water received in 1899 was greater than in 1897. The general effect indicated is an increase of nitrogen for the whole plot.

§ 92. No effort was made to follow the formation of nitrates in the soil from day to day, or from week to week, but the amount of this substance eliminated in the ground water was determined weekly for the seasons of 1897-98-99 and 1900. The nitrates have been determined in but a single series of soil samples, representing the first and second two inches of the soils which had received no manure. The water-soluble, analyses of which have already been given, was determined in the same set of samples. The results are given in parts per million of the air dried soil.

* Sample F is the subsoil.

TABLE XX.—NITRATES IN THE SOIL.

	Water-Soluble.	Nitrogen.	Nitric Acid.	Potassic Nitrate.
A—First two inches....	39,314.0	7.075	31.746	50.930
B—First two inches....	7,513.0	36.062	161.814	259.598
C—First two inches....	20,544.0	12.326	55.308	88.730
D—First two inches....	8,000.0	19.200	86.152	138.214
A—Second two inches..	......	Trace	Trace	......
B—Second two inches..	3,890.0	0.389	1.745	2.800
C—Second two inches..	8,130.0	1.626	7.296	11.705
D—Second two inches..	8,640.0	2.073	9.306	14.929

§ 93. This indicates that, at the time these samples were taken, a very small percentage of the total nitrogen existed in the soil in the form of nitrates, and that the first two inches of this soil was at the time very much richer in nitrates than the second, also that different portions of the plot contained very different amounts of these salts.

DO SOIL SAMPLES ABSORB NITROGEN ON KEEPING?

§ 94. The most of the nitrogen determinations given in this bulletin were made on fresh samples, but occasionally we found it desirable to check a determination on an old sample, one that had been in the sample room for one or more years. The samples are kept with ordinary care, but not always sealed. The samples which suggested this question had been carefully stoppered and kept two years, but had not been sealed. In order to answer this question, a sample was taken and the nitrogen determined in duplicate. The remaining portion of the sample was dried as usual, bottled, corked and kept in the laboratory for fifteen months and the nitrogen redetermined in duplicate. The average of the first two determinations was 0.1058 per cent., that of the last two 0.1066 per cent. The difference is 0.0008 per cent., which is possibly to be attributed to analytical differences, rather than to the absorption of nitrogen in any form from the atmosphere of the laboratory. If, however, we accept the analytical results as correct, they show that the sample gained a quantity of nitrogen, due to increase of micro-organisms, corresponding to 28 pounds per acre, taken to a depth of one foot.

HUMUS IN THE SOIL.

§ 95. The humus in this soil is not especially low, as is the rule with our soils in general. The earlier determinations being slightly under one per cent., while the later ones average about one and one tenth per cent., a gain of about three tenths of one per cent. I thought that the physical condition of the soil and the presence of so large an amount of soluble salts would probably modify the character of the humus to a sufficient extent to cause some marked changes in properties or composition sufficient to justify its analysis. This was not found to be the case. The humus is very much like

other humus, and is much more like the humus of the Southern and Eastern States, as given by Hilgard, than the humus of the prairie soils of the arid regions, which are supposed to be rich in nitrogen, carrying, according to Hilgard and Jaffa, as high as 18.5 per cent.

§ 96. A quantity of soil was treated as usual for the preparalion of humus, extracted with ammonia and the solution precipitated by acidulation with hydrochloric acid. The precipitated humus was washed and dried. It formed a black mass with a strong vitreous lustre and conchoidal fracture. Its reaction was acid with litmus. The precipitated humic acids alone were preserved. The portion soluble in dilute hydrochloric acid and water was neglected, as we thought to obtain the whole of the soluble humic substances by evaporating the ammoniacal soil extract to dryness and examining it, but it was found to contain so much ammonic chlorid that the results were unreliable. It seems to be a difficult matter to wholly avoid this error when handling larger quantities of soil. The results obtained indicate a very much higher percentage of ash in the ammoniacal extract than in the precipitated humus, but on the other hand a materially lower percentage of carbon.

The elementary analysis of the precipitated humus resulted as follows:

TABLE XXI.—ELEMENTARY ANALYSIS OF PRECIPITATED HUMUS.

	Per Cent	*Per Cent.*
Carbon	41.787	45.727
Hydrogen	4.804	5.267
Nitrogen	5.536	6.051
Oxygen	39.254	42.955
Ash	8.619	......
Total	100.000	100.000

I have deducted the ash and given the carbon, hydrogen, etc., in parts per hundred to make their quantitative relation more evident, not to indicate that they form a definite compound. It is noticeable that the percentages throughout are almost identical with those given for humocrenic acid obtained by precipitation as the lead salt from a solution prepared from a sample of Russian black earth.

HUMUS AS A SOLVENT.

§ 97. The ash probably forms an integral part of this precipitated humus, that is the humus carried this inorganic part in such a state of solution that it retained it when thrown down by the dilute hydrochloric acid. The total sulfur present equalled 0.44 per cent. of the precipitated humus, equal to one and one tenth per cent. of sulfuric acid (anhydrid). The potash taken into solution by the four per cent. ammonia equalled 0.385 per cent. of the humus dissolved. The ash obtained from the filtered am-

moniacal solution, by evaporation and incineration, is rich in lime, that from the precipitated humus contains only a very slight trace of it. The ash from both, the ammoniacal solution of humus and the humus precipitated from it, is relatively rich in phosphoric acid.

§ 98. We made an attempt to determine the ash carried into solution by the extraction with ammonia. The results were not satisfactory. The solutions were all filtered repeatedly, but owing to the intense color of the solutions we could not feel assured that some of the variations in our results might not have been due to a turbidity in the solution. Our results indicated roughly one per cent.; this is probably too high, but it suffices to show that a very considerable portion of the whole mass of soil is soluble in this ammoniacal humus solution.

§ 99. Authors have insisted upon the value of humus as a solvent for the inorganic constituents of plant food in the soil. Free ammonia and ammonic salts are probably present in small quantities, as previously shown, and we have in the humus, dissolved out of the soil by a dilute ammonia solution, phosphoric acid, sulfuric acid, potash, lime, iron and an abundance of silicic acid, which are not only food for the cultivated plants, but also for the micro-organisms which we believe effect the change of the nitrogen in the humus into nitric acid, respectively into nitrates, rendering it also available food for the plants. This seems an important function to attribute to humus, amounting in but few instances to more than one and a half per cent. of the soil, and yet it is justified. Our method of treatment or extraction does not faithfully represent the soil conditions, and therefore exaggerates its importance. This is probably less true than it appears to be, for the acids and bases forming the salts of the soil are not in the fixed and quiescent condition in which we usually think of them. On the contrary, there are certainly as many, and possibly more, changes going on than there would be in a mixture of the same salts in simple aqueous solution, and we know that there would be many. We have seen that there is probably free ammonia and ammoniacal salts in the soil, both of which aid the humus in its action by favoring its solution. The phosphoric acid extracted with the humus was determined at the beginning of the experiment and again after three crops had been grown on the plot. The results are shown in the following tables of analyses.

SOME RESULTS OF THREE SEASONS' WORK.

§ 100. The plot had received but little cultivation before I began my experimentation with it, and was in such bad condition that a part of it was so good as useless for any agricultural purpose. That this was not due to any lack of plant food is indicated

by the chemical analyses and also by its subsequent deportment under cultivation.

§ 101. The analyses of the samples taken at the beginning of the experiment may be summarized as follows:

TABLE XXII.—ANALYSES OF SOIL AT BEGINNING OF EXPERIMENT.

SOIL, SAMPLES TAKEN 1897.		Nitrogen. Per Cent.	Potash. Per Cent.	Phosphoric Acid. Per Cent.	Humus. Per Cent.	Phosphoric Acid in Humus, Calculated on Soil. Per Cent.
A	Spring	0.0937	1.495	0.112	0.815	0.0384
	Fall	0.0938	1.528	0.086	0.712	0.0333
B	Spring	0.0882	1.003	0.064	0.945	0.0205
	Fall	0.1022	0.978	0.128	0.910	0.0345
C	Spring	0.0882	1.443	0.081	0.736	0.0296
	Fall	0.1015	1.457	0.115	0.740	0.0396
D	Spring	0.0959	1.443	0.061	0.660	0.0288
	Fall	0.1083	1.372	0.099	0.846	0.0294
E	Spring	0.1295	0.876	0.070	0.808	0.0486
	Fall	0.1191	0.936	0.138	1.030	0.0537
F*	Spring	0.1040	0.854	0.054	0.574	0.0384
	Fall	0.0996	0.750	0.122	0.502	0.0334

* F is a subsoil corresponding to soil E.

§ 102. The samples, "Spring" and "Fall," represented in the above table were not taken by the same person, nor were they taken so nearly from the same spot that they can be considered as duplicates, still the agreement throughout is as close as can be expected, except in the case of the phosphoric acid. The analyses were made by the same person, so that the personal equation is eliminated, but the differences in the phosphoric acid are great, varying from 60 to 126 per cent. of the lower percentage found. It is possible that this variation between the spring and fall samples may be in the sampling, either in the field or in the laboratory, but every care was exercised to get this entirely correct. Duplicate analyses were made on most of these samples and good agreement was obtained, so that after making every allowance for errors in the analytical work and in the sampling there is a difference in favor of the samples taken in the fall. That the whole of the phosphoric acid present went into solution, there can be no doubt. We have examined the insoluble residues obtained from these digestions and have been unable to find any phosphoric acid. I have no explanation to offer.

The only remnants of the crop which could have been present in the fall samples were the fine roots which we could not remove, and such leaves as might have fallen and decayed during the season, all others were removed from the field. With these explanations, we must abide by our results even if there is a difference of 126 per cent. in the amount of phosphoric acid in practically the same soil, sampled in the spring and fall of the same year.

§ 103. It is not a matter for surprise that samples taken three years later, after the refuse of several crops and a liberal amount of manure had been incorporated with the soil, should show differences, indicating an improvement in the soil. The subsoiling, deep plowings, and the continued cultivation, together with the fact that the ground was left thrown up into rather high and rough ridges during the winters, exposing the deeper portions of the soil to the effects of the winter seasons—all tend to mix and improve the soil; but there is only one thing which has added any mineral matter to the soil, that is the application of the manure, which was made to alternate sections of the plot, as has been stated elsewhere.

Samples taken in the autumn of 1899 gave the following results:

TABLE XXIII.—ANALYSES OF SAMPLES OF SOIL TAKEN IN 1899.

NUMBER OF PLOT.		Nitrogen. Per Cent.	Potash. Per Cent.	Phosphoric Acid. Per Cent.	Humus. Per Cent.	Phosphoric Acid in Humus, Calculated on Soil. Per Cent.
3	Manured	0.1152	1.1700	0.1343	1.1000	0.0767
	Not manured	0.0935	0.9990	0.1215	1.0500	0.0735
2	Manured	0.1295	1 3030	0.1567	1.0600	0.0607
	Not manured	0.1355	1.0994	0.1695	1.2550	0.0255
1	Manured	0.1312	0.9540	0.1215	1.2800	Lost
	Not manured	0.1316	0.8493	0.1727	1.0900	0.0670

These numbers, 3, 2 and 1, manured and not manured, do not correspond exactly to A, B, etc. The five sections A, B, C, D and E, were made into six sections to study the effects of manure upon the crop and soil. No. 3 manured corresponds to part of A, while No. 3 not manured corresponds partly to A and partly to B, and so on. The plot was 600 feet long, and the manured and not manured sections were each 100 feet long. The samples were taken from the middle of the respective plots at the end of the season and nine months after the application of the manure.

The results indicate an increase in the humus present, but the analyses do not show conclusively that this was due to the application of manure, though the indications are that it had a perceptible effect. The results in regard to the phosphoric acid are difficult to bring into harmony with the facts as recorded or with one another, but the general results are in the same direction as those obtained from the samples taken in the autumn of 1897, namely, an increase. The increase in the nitrogen is not very pronounced, but seemingly quite general. The most marked result, however, recorded in the last table is the increased extent to which the phosphoric acid present in the soil can be extracted with the ammoniacal solution of the humus. It is entirely out of the question to attribute this large percentage of the phosphoric acid found in the humus solution to any turbidity which, owing to the dark color of the solution, might have passed through the filter and escaped detection. I regret that I did not examine the hydrochloric acid with which the soil was washed to determine how much phosphoric acid was removed by it. An inspection of the table shows that from 14 to 60 per cent. of the total soluble phosphoric acid was found in the ammoniacal humus solution.

§ 104. If we recall the amount of nitrogen found in the precipitated humus, about 5.5 per cent., we will see that the observation made on the phosphoric acid is also applicable to the nitrogen, only in a different degree. The humus contained from 14 to 60 per cent. of the former, but 40 or more per cent. of the latter.

The manure which was applied to this soil was analyzed, the results, together with some observations on its effects, etc., are given in Bulletin 58, pp. 13, 18, 36, *et seq.*

The sulfuric acid was determined in the samples taken in 1899, giving for No. 3, manured and not manured, 1.320 per cent. and 0.350 per cent.; for No 2, 0.333 and 0.633 per cent.; for No. 1, 0.683 and 0.314 per cent. If we compute this into sodic sulfate, as we have done elsewhere, it will be seen that the sulfates have either been removed or carried down into the soil beyond the reach of our sample, and either is an improvement.

§ 105. The results of this experiment are readily recognizable in the improved condition of the soil. The figures given as representing the composition of the samples taken in the autumn of 1899, may be right or wrong, but the improvement in the soil is much more pronounced than any analytical results can indicate, and after all of our seeking after facts and explanations, we are fully satisfied that there is much in the aggregate effect, whether it has been produced by moisture, æration, frost or sunshine, that has escaped our analysis, and while it is perfectly patent, it is not subject to clear and definite formulation. The application of manure pro-

duced some effects which we have noted at some length in Bulletin 58, especially those upon the crop, and we have incidentally stated that the salts in the ground water were influenced by the same, but we have acknowledged an effect, by stating that it improved the mechanical condition of the soil, which we fail to explain, because we do not recognize in what this actually consists. There are certain bold features in this improved condition which we readily perceive, but we cannot tell to what agents this improvement is to be attributed, nor the degree in which any particular agent has participated.

ANALYSES OF SOME COLORADO SOILS.

§ 106. I append a table of hitherto unpublished analyses of some soils from this State. These analyses were made some years ago by Mr. Chas. Ryan, under the direction of Dr. D. O'Brine, my predecessor.

There is no description or data of any kind given with the analyses. The record does not even show the locality from which the samples came more specifically than somewhere within a Colorado county. As a matter of fairness, I feel it due to Dr. O'Brine to state that, according to my information, he is not at fault for this, but that, owing to a bit of mistaken economy, he was not able to take the samples as he wished to, and did not obtain the data, whose lack detracts so materially from an otherwise commendable piece of work.

§ 107. The history of some of the samples is know, but so far as the record shows, there is nothing to indicate whether the samples are of virgin or highly cultivated garden soils, whether they are samples taken from excavations in city streets, or have been scratched from between the rocks of the hills.

The presumption was, and ought still to hold, in spite of the few exceptions of which we have definite knowledge, that the samples fairly represent the virgin soils of the State. If they do not, it is to be regretted that this work has been done to such little purpose.

TABLE XXIV.—ANALYSES OF SOME COLORADO SOILS.

COUNTY.	Insoluble.	Silicic Acid, Sol.	Sulfuric Acid.	Carbonic Acid.	Chlorin.	Phosphoric Acid.	Potash.	Soda.	Lime.	Magnesia.	Ferric Oxid.	Aluminic Oxid.	Manganic Oxid.	Moisture.	Ignition.	Total.	Nitrogen.
Arapahoe	69.79	7.05	0.05	0.05	0.07	0.08	0.16	0.54	3.25	0.03	2.69	10.03	....	2.16	3.98	99.93	0.10
Archuleta	72.48	4.05	0.13	0.54	0.04	0.20	0.26	0.35	1.31	0.08	2.29	9 90	....	2.79	5.45	100.56	0.19
Baca	63.00	7.44	Tr.	1.28	0.04	0.05	0.22	0.20	2.51	0.66	2.35	7.48	....	5.00	9.25	99.48	0.16
Boulder	70.68	3.90	0 14	....	0.06	0.16	0.75	1.97	0.41	0.06	6.38	7.79	....	3.10	4.68	99.99	0.20
Boulder	67 50	10.00	0.22	0.35	....	0.14	0.45	0 95	2.25	0.85	2.04	6.96	0.09	....	8.28	100.09	0.11
Chaffee	69.01	5.06	0.39	....	0.02	0.05	0.17	0.95	2.60	1.14	1.57	10 31	....	2.33	6.33	99.95	0.26
Cheyenne	72.57	6.14	0.63	....	0.03	0.04	0 30	0.25	1.02	0.56	0.22	8.88	..	2.80	7.16	100.60	0.13
Clear Creek...	65.50	5.00	0.10	...	0.04	0.02	1.69	1.34	0.96	0 75	7.08	8.32	....	3.14	6.17	100.11	0.27
Conejos	70.24	.....	0.02	0.38	0.03	0.06	0.63	1.98	1.46	0.44	2.94	5.07	....	3 50	13 10	99 90	0.23
Costilla	78.50	1.27	0.39	0.01	0.06	0.07	0.26	2.31	1.65	0.14	1.42	8.03	....	2.17	4.57	100.85	0.18
Custer	59.85	2.33	0.63	7.55	0.02	0.02	0.49	0.37	9.39	0.83	1.24	1 58	....	1.81	12.96	99.07	0.11
Delta.....	76.77	1.56	0.11	1.45	0.05	0.01	0.45	0.18	2.03	0.83	4.50	8.40	....	1.96	1.87	100.17	0.08
Douglass......	82.04	0.08	0.20	0.02	0 07	0.03	0.37	0.51	0.24	0.28	2 54	8.34	....	1.42	3.10	99.24	0.13
Eagle	73.67	1.80	....	3.49	0.09	0.03	0.10	0.16	5.32	0.91	2.51	5.55	....	1.34	5 04	100.01	0.09
Elbert.........	86.35	0.69	1.19	0.48	0.04	0.01	0.46	0.93	0.12	0.42	1.54	3.83	....	1.34	2.66	100 06	0.12
El Paso	74.37	2.13	0.06	1.68	0.05	0.01	0.20	0.70	0.28	0.21	1.97	10 57	....	2.23	5.52	99.98	0.23
El Paso	79.35	5.35	0.42	0.31	....	0.49	0.35	0.30	0.65	0.25	1.25	4.25	0.08	....	7 09	100 15	0.20
Fremont	74.65	2.70	0.49	0.46	0.06	0.04	0.49	0.12	1.49	0.29	3.75	10.90	...	1.49	2.97	99.90	0.07
Garfield	72.68	5.20	0.44	0.21	0.06	0.14	1.38	0.63	0.71	....	2.07	8.27	..	2.82	5.32	99.93	0.16
Grand	72.01	6.09	0.53	1.00	0.05	0 05	0.37	0.22	0.70	0.16	1.06	3.88	....	3.80	11.03	100.95	0.25
Gunnison	67.00	5.51	1.46	....	0.05	0.01	0.75	0.86	2.05	0.58	2.86	10.24	....	2.30	6.21	99.98	0.13
Jefferson......	60.72	10.56	0.99	....	0.05	0.01	0 57	0.78	2.34	0.17	6 17	9.77	....	3.06	4 72	99 98	0.12
Kiowa.........	70.53	7.36	0 41	....	0.03	0.06	0.27	0.31	5.67	0.02	1 55	7.35	....	3.55	2.92	100.03	0.24
Kit Carson....	73.11	7.11	0 61	0.02	0.07	0.03	0.41	0.30	3 00	0.66	1.93	6.06	....	3.57	3.14	100 02	0.14
Las Animas...	77.72	5.32	0.45	1.01	0 04	0.90	0.25	0.11	1.55	0.11	2.93	4.70	....	1.66	3.70	100.45	0.06
La Plata......	75.74	7.15	1.14	....	0.02	0.10	0.76	0.22	0.93	0.13	2.59	4.06	....	1.48	5.66	99.98	0.16
Larimer	65.35	6.38	1.44	4.90	0.03	0.08	0.12	0.56	6.72	0.28	2.18	5.96	....	1.80	4.10	99.90	0.08
Larimer	81.50	5.67	0.31	0.40	....	0.28	0.42	0.36	1.15	0.35	2.17	4.10	0.03	....	3 25	99.99	0.10
Larimer	67.47	7.88	....	1.96	0.09	0.09	0.15	0.35	3.43	0.56	2.01	7.30	....	2.88	5.75	99.92	....
Lincoln	78.43	10 74	0.36	....	0.03	0.15	0.24	0.71	0.48	0.50	1.79	3.90	....	1.17	2.00	100.50	0.12
Logan	78.08	8.30	0.05	....	0.05	0 03	0.70	0.46	1.36	0.18	1.76	6.19	....	1.57	2 02	100.12	0.11
Mesa	72.49	10.41	1.66	1.65	0.03	0.11	0.11	0.50	3.43	0.70	2.45	3.36	....	1.00	2.11	100.01	0.01
Montrose	66.00	1.75	1.23	5.32	0.06	0.04	0.78	0.87	6.81	0.08	2.68	6.25	....	2.45	5.76	100.04	0 05
Montezuma ...	77.60	2.98	1.35	....	0.06	0.05	1.29	0.55	0 38	1.49	2 13	6.56	....	2.64	2 93	99.99	0.09
Morgan	84.94	2.04	0.39	0 06	0.05	0.04	0.56	0.86	0.19	0 05	0.99	5.53	....	1.33	2.67	99.60	0.16

TABLE XXIV.—ANALYSES OF SOME COLORADO SOILS—(Continued).

COUNTY.	Insoluble.	Silicic Acid, Sol.	Sulfuric Acid.	Carbonic Acid.	Chlorin.	Phosphoric Acid.	Potash.	Soda.	Lime.	Magnesia.	Ferric Oxid.	Aluminic Oxid.	Manganic Oxid.	Moisture.	Ignition.	Total.	Nitrogen.
Ouray	55.12	6.55	0.97	6.54	0.05	0.19	1.95	0.48	8.16	0.27	1.86	10.85	....	1.48	5.69	100.16	0.13
Otero	80.23	3.03	0.50	1.15	0.09	0.14	0.91	1.52	1.76	0.16	2.38	4.45	....	1.55	3.25	100.12	0.12
Park	79.55	2.67	0.54	....	0.05	0.07	0.65	0.45	2.33	0.55	0.95	2.10	....	2.04	7.90	99.85	0.32
Pitkin........	70.50	3.95	0.85	3.16	0.03	0.08	0.46	0.81	2.27	0.28	2.89	4.60	....	2.54	7.62	100.04	0.26
Phillips	73.43	4.00	1.86	1.98	0.04	0.25	0.15	0.75	1.45	1.89	2.31	5.68	....	2.96	3.78	100.53	0.08
Prowers.	69.90	8.10	0.60	....	0.03	0.09	1.69	0.54	1.44	0.79	2.78	5.94	....	2.65	5.79	100.36	0.13
Pueblo	75.84	5.11	0.10	0.36	0.04	0.08	0.22	0.16	1.02	0.54	3.71	5.66	....	2.19	4.75	99.36	0.13
Rio Blanco ...	69.88	4.35	1.12	1.95	0.04	0.18	0.78	0.27	1.45	0.43	2.75	7.13	....	2.56	6.64	99.55	0.24
Rio Grande ...	76.03	4.64	0.67	....	0.09	0.09	0.90	0.77	1.55	0.95	5.40	5.09	....	1.48	3.00	100.66	0.09
Routt	67.04	6.14	0.66	....	0.04	0.20	0.69	0.57	1.21	0.53	3.33	6.73	....	3.56	9.20	99.90	0.24
Saguache	65.59	9.46	1.10	....	0.09	0.11	0.26	0.99	1.64	0.63	3.60	5.33	....	3.97	7.41	100.18	0.24
San Miguel ...	69.61	5.28	0.47	1.19	0.04	0.06	0.11	0.44	2.10	0.67	3.38	6.08	....	3.60	7.30	100.33	0.31
Sedgwick	69.43	5.87	1.20	2.47	0.03	0.30	0.33	0.84	3.46	0.32	2.21	5.40	....	2.33	6.34	100.58	0.11
Washington ..	73.33	6.80	0.41	1.02	0.02	0.05	0.56	0.16	1.04	0.28	2.01	5.56	....	3.56	4.75	99.53	0.12
Weld	79.76	6.36	1.13	....	0.05	0.11	0.54	0.16	1.38	0.42	2.43	3.52	....	1.48	2.52	99.86	0.07
Weld	78.17	7.75	0.26	0.28	0.05	0.31	0.38	0.30	0.97	0.40	3.01	3.96	0.04	....	4.42	100.26	0.13
Yuma	67.90	5.31	1.03	0.11	0.02	0.29	1.53	0.84	3.43	1.15	4.88	7.55	....	1.43	4.83	100.30	0.07
*Otero†.......	74.27	10.50	0.05	0.68	0.02	0.04	0.41	0.78	1.38	0.71	4.34	2.43	0.17	1.44	3.54	100.76	0.08
Otero‡	84.06	5.88	0.04	0.31	0.01	0.04	0.26	0.33	0.60	0.22	3.38	1.66	0.22	0.74	2.42	99.98	0.05
Otero§	78.22	9.87	0.06	0.27	0.02	0.02	** 0.01	0.70	1.05	0.46	4.24	1.36	0.22	0.89	2.55	99.94	0.06

* Analyses of melon soils from Fowler, taken Jan. 27, 1899, analyst F. C. Alford. Digestion with acid sp. gr. 1.115 for 10 hours.
† Humus 0.14. ‡ Humus 0.08. § Humus 0.10.
** Examination of this sample shows very little feldspar in it.

SUMMARY.

§ 108. The "alkali" salts in the soils and waters of Colorado are essentially mixtures of the sulfates of lime, magnesia and soda.

§ 109. The soils of the eastern slope of the Rocky Mountains and of the plains lying to the east in Colorado, have in general a very similar composition, as shown by the composition of the soil mass.

The mineralogical composition of these soils is very similar, the principal variation being in the ratio of the quantities of the minerals present.

§ 110. The surface soils of this section of Colorado probably owe their mineral constituents to a common source, the schists and granites of the Colorado range.

§ 111. The feldspar, orthoclase, an almost universal constituent of our soils, serves as a source of potash and also of hydrous silicates under ordinary cultural conditions.

§ 112. The readiness with which the chemical reactions take place and their character, as indicated by the salts present in the ground waters, probably have a direct and important bearing upon the fertility of the soil. The loessial soils of the plains agree with the ordinary prairie soils in the chemical composition of their mass and in the general results of the agricultural analysis, but not in the mechanical analysis.

§ 113. The analyses of the whole soil mass and of the different portions of the fine earth, suggest important differences between the unchanged rock particles in the soil and the finer portions which have suffered change or are the products of alteration.

§ 114. The aggregate amount of soluble salts per acre whose movement is effected by the water falling on or supplied to the surface, or by its evaporation from the surface, is large; we make it nine tons in one instance. The application of water, irrigation, may carry the soluble salts so deep into the soil that a long time may be required for them to come near to the surface again.

§ 115. The chemical analyses give us no hint of the very great improvement which was effected in this soil by three, really four, years experimentation with it. Our question was one of conditions and not of composition, so far as its purely agricultural features were concerned.

§ 116. The water-soluble in the soil and the incrustations formed upon the soil are very different in composition.

§ 117. The incrustations are formed by the evaporation of water from the surface of the soil, which, owing to the deportment of the solutions of these salts toward capillary action, and the chemical instability of the hydrated salts themselves, effects their separation from the soil solutions.

§ 118. The water-soluble in the soil is not identical with ground water solutions, probably due to reactions dependent upon the relative masses, which react upon each other within the soil and during the extraction.

§ 119. The reactions near the surface of the soil are quite different from those more remote. This is indicated by the solutions yielded by samples taken to depths of two and four inches.

§ 120. There is, in the samples of soil examined, both free ammonia and ammoniacal salts, which we interpret as indicating unfavorable biological conditions, which view is materially strengthened by the nitrates in the ground waters.

§ 121. There is a significant gain in the total soil nitrogen during the time of the experiment, which may have been favored by, but was not dependent upon, the application of manure.

§ 122. The nitrates in the first two inches of this soil are from nine times to two hundred times as great as in the second two inches, corrobative of the suggested reduction in certain zones of the soil.

§ 123. Air dried soil samples can be kept for a year or more with ordinary precautions, without material change in their nitrogen content.

§ 124. The humus in this soil is nearly as abundant as in average Eastern soils, and we were unable to find anything about it markedly different from ordinary humus. It is unlike the humus of arid soils, in that it is not so rich in nitrogen as they have been found to be.

§ 125. The solutions of the humus carried relatively very large amounts of silicic acid, phosphoric acid, potash and lime. The precipitated humus did not carry much lime.

§ 126. The effect of the cultivation, manuring, etc., for three seasons, may be summed up by stating that the store of plant food in the surface soil, taken to a depth of ten inches, was actually increased. This, however, was the lesser part of the improvement, the greater part lay in the betterment of the general conditions, whose best features cannot be shown by chemical analysis, or expressed in any formula.

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The Agricultural Experiment Station

OF THE

Agricultural College of Colorado.

RELATION OF BOVINE TO HUMAN TUBERCULOSIS.

G. H. GLOVER.

TUBERCULIN TESTS OF THE COLLEGE HERD.

B. C. BUFFUM.

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Plate I. Kate—Jersey Cow, Apparently Healthy, but Badly Diseased with Tuberculosis.

PART I.

REVIEW OF THE ARGUMENTS OF THE RELATION OF BOVINE TO HUMAN TUBERCULOSIS.

BY GEORGE H. GLOVER.

The recent test of the College herd with tuberculin and the consequent discovery of tuberculosis among cattle which were supposed to be in perfect health has led to some controversy; on the one hand by those who, because of their knowledge gained by actual observations and experiments, and who having been trained to think and reason to logical conclusions, are warranted in expressing themselves; and on the other hand by those who are not so warranted.

One thing in particular, more than any other, has inspired the issuing of this bulletin, viz: The evidence everywhere extant, that since the stand recently taken by Dr. Koch, there has settled upon the public a determined disposition to belittle the whole matter and throw precautionary measures to the wind. We urge upon all the warning that the difference between human and bovine tuberculosis has not yet been settled finally, and that precautionary measures for preventing the spread of the disease by butter and milk cannot be safely abandoned. It is one of the misfortunes accompanying the deliverance of such an uncompromising thesis as that by Dr. Koch that obscurantists of every dye make it responsible for conclusions which are not warranted by the facts in the case. It cannot be too strongly emphasized that even if it be proven that bovine tuberculosis is not communicable to the human race, the necessity for the most scrupulous cleanliness in the management of cows and their milk production is as great as ever. This incident coupled with the perfectly reliable information which we possess that a large percentage of the dairy cows in Colorado supplying milk to our towns and cities (especially the latter) are consumptive, and that it is yet far from proven that this disease is not communicable to human beings by the use of such milk; and further, lest the recent stand taken by Dr. Koch results in a criminal laxity or indifference: have together inspired the issuing of this bulletin. It is not claimed that we have made any new or startling discoveries: the work among the College herd, so far as it has gone, has in every instance corroborated our claims

(and which are in harmony with a great majority of the foremost investigators in this line of research) and the conclusions arrived at by reliable authorities are here compiled in as brief a manner as possible, hoping to accomplish something toward arousing the masses from their lethargy relative to the importance of this serious condition as affecting the animal wealth and the possibility of its being a prolific source of disease in the human family.

In the annual report of the Veterinary Science Department of the College, the assertion is ventured that the public in general in judging of veterinary science is prone to look upon it from a purely commercial (and in a lesser degree humanitarian) standpoint and do not take cognizance of its broader sphere of usefulness, viz: what the science is doing for the health and lives of the people themselves. It is in keeping with this thought that we venture a step further and assert that the educated veterinarians are among the leaders in the van now vigorously prosecuting the research that is being made in regard to the relation of human to bovine tuberculosis.

Tubercular consumption is one of the most dreadful and unfortunately, most common diseases of mankind. People of all ages or circumstances, and environments, regardless of climate, nationality, or degree of civilization, are subject to infection, if exposed under proper conditions. None are immune, and the present conditions prevailing, it looks as if we are doomed to become a sickly, consumptive race, and that its ravages must eventually almost wipe the human race from the face of the earth.

The greatest good to humanity will be accomplished along the line of preventing disease and while the prevailing medical thought now, both human and veterinary, is absorbed in new remedies, and is alive with keen expectancy as to the possibilities of sero-therepy, (which seems almost beyond conjecture) yet, after all, we must admit that prophylaxy (prevention of disease) is of vastly more importance than the discovery of new cures.

NOT A NEW DISEASE.

History from the earliest times has been replete with accounts of this "great white plague" and the theories advanced to account for its etiology and pathology have only been equalled in variety by the persistency with which they have gone wide of the mark.

At one period it would be considered contagious, at another this would be thought improbable, again several of the local manifestations of this disease would be looked upon as separate and distinct diseases; at other times it has been confounded with diseases that had no relation to it whatever. It seems strange, but it is nevertheless true, that while this disease has been known as affecting the lower animals, and a scourge in man (now claiming ten per cent. of the death rate) during all these centuries comparatively nothing was accomplished in working out its etiology or pathology until within the last fifty years Villimian and Koch have placed the matter on a sound basis.

IS A GERM DISEASE.

Long before any suspicion existed as to the relation of bacteria to fermentation and disease, various scientists, at different times, had suggested that resemblance existed between the phenomena of certain diseases and fermentation, but the idea that a virus or contagium might be something of the nature of a minute organism, capable of spreading and reproducing itself, had never been thought of. The first vague notion in this direction was no doubt the ferment theory of Cagniard-Latour in 1828. In 1837, Schwann showed that fermentation and putrefaction were intimately associated with the presence of organisms derived from the air. By 1862 Pasteur had buried forever that "will-o-the-wisp" spontaneous generation and repeated and extended such experiments and proved the way for a complete explanation of the anomalies.

From 1870 onward the "germ theory of disease" had passed into general acceptance and now has become an assured fact, and in a sense has revolutionized the theories of disease and treatment in that now a persistent war is waged on the micro-organisms which excite the disease, and s not based altogether upon symptomology. Robert Koch first succeeded in demonstrating and isolating the specific bacillus of tuberculosis and achieved its artificial cultivation the use of blood-serum.

TRANSMISSIBILITY.

The origin of the germ theory of disease and the discovery of the specific bacillus of tuberculosis are but parts of an old story now relegated to history, but when we

look up the subject of the transmission of these germs from one animal to another, including man, we are at first surprised and then astounded at the seriousness of the conditions actually existing, and the grave possibilities which the tireless investigation by scientists may yet have in store for us.

NOT CURABLE.

Favorable climatic influence will often stay the progress of the disease for a time at least, but no climate or therapeutical agent has ever been discovered which can in the true sense be called a cure. If ever anything is accomplished in either curing or preventing the disease it will most likely be in the direction of sero-therapeutics, but this is conjectural to say the least.

RELATION OF BOVINE TO HUMAN TUBERCULOSIS.

That tuberculosis is transmitted from one animal to another, and more especially from the cow to other domesticated animals, has been repeatedly proven so that it is considered a waste of time now to rehearse them. The whole subject is summarized by Dr. John Repp in an article read before the Iowa Tuberculosis Convention in this way: "Enough has been done to prove beyond the peradventure of a doubt, that tuberculosis may be transmitted through the milk and the food structures of tuberculous animals, to the animals that consume these products or are inoculated with them, upon this all students of the subject agree. This much has been proven, but these facts do not decide the important question at issue, viz: whether or not tuberculosis is transmitted from animal to man, nor would they if they were multiplied ad infinitum, they only furnish a basis from which we may reason, for this purpose they are invaluable, as they establish the premise that the meat and milk of animals do, at times, contain living virulent tubercle-bacille."

If some of the incredulous will show the faith of their convictions by submitting themselves to a few "hypoes" of bovine bacillus-tuberculosis, or by voluntarily injecting a few of the same, it will supply the last link in the chain of evidence necessary to convict the cow of transmitting the disease through her milk and meat to her human benefactors.

As there is little probability of anyone offering in good faith to sacrifice themselves for the cause of science, let facts

be submitted which, while circumstantial, are sufficient to lead us beyond the range of probability, to the very verge of absolute certainty. Our certain knowledge on the following may be analyzed as follows:

TRANSMISSION OF TUBERCULOSIS FROM ONE ANIMAL TO ANOTHER NOT INCLUDING MAN.

1st, by Meat.—Experiments, by their positive results, demonstrate that tuberculosis is transmitted in this way, both by artificial inoculation with the muscle juice of tuberculous animals, as well as by feeding the diseased tissue.

2d, by Milk.—This has been as fully demonstrated by a long series of experiments consisting of the inoculating of different animals with tuberculous milk, both from cows with diseased udders as well as those not so diseased, and further by the feeding of calves, rabbits, pigs, etc., with milk from tuberculous cows.

TRANSMISSION TO MAN.

There is, as previously stated, for reasons well understood, no opportunity to secure evidence by artificial methods. By natural methods the evidence consists of recorded observations, which have been made by close observers, covering a period of many years, of people who have used the milk and meat of tuberculous cattle. Dr. John Repp has gathered some statistics bearing on this point which are most interesting, as follows: "Oliver reports that in a young ladies boarding school, five girls, the children of healthy parents, died of tuberculosis of the intestines. The cow which had for many years supplied the school with milk was found to have generalized tuberculosis including the udder.

"Two daughters of a Scotch family of good health, who were brought up on milk of tuberculosis cows, died of tuberculosis. Two sons in the same family, wno did not use the milk remained healthy." "Stang reports the case of a five-year-old boy of sound parentage and ancestry, who died of tuberculosis. The cow whose milk this boy used was found badly tuberculous." "Demme reports the case of four infants in the Children's Hospital at Berne, the offspring of sound parents, that died of intestinal and mesenteric tuberculosis. He was able to exclude all other sources of infection and to decide that they had been infected by

the ingestion of the milk of tuberculous cows." "Hills mentions the case of a child twenty-one months old of a friend of his, which drank the milk of a highly tuberculous cow for one week while on a visit to his uncle, and three months later this child died of intestinal tuberculosis. Other sources of infection could be excluded. A second child brought up on sterilized milk is still healthy." "Hills also reports the death of a boy four years old, at Yonkers, New York, from tuberculor meningitis. The infection was traced to the milk of two cows of whose milk the boy had drank and which proved on autopsy to be tuberculous." "Ernest reports the death of three children of one family, from tuberculosis. These children had used the milk of a cow which later died of advanced tuberculosis including the udder.

"Stalker and Niles report that five persons, between twenty and thirty years of age of healthy ancestry, died of tuberculosis within a period of two years. On the farm where these deaths occured they found seventeen cattle suffering from tuberculosis, and other cattle had previously died of this disease.

"Leonhardt reports the death from tuberculosis of the meninges, intestines and mesentary, of two children fed on the milk of a tuberculous cow. Sontag reports the case of a six-months-old child of healthy parents, which died of tuberculosis and which had been fed on the milk of a tuberculous cow. Hermsdorf has reported the case of a child, dead of intestinal tuberculosis, which had been fed on the milk of a tuberculous cow. Rich reports that a young man of healthy parents, who died of tuberculosis, had used plentifully of the milk of a herd of seventy-four cattle, sixty-five of which were tuberculous, some of them markedly so. Also another young man of the same family died of tuberculosis two months later. Rich destroyed eighty cattle out of the herd, that is about 90 per cent, of the entire herd. Also a young woman died of tuberculosis, and a month later the cows, whose milk she had used, died of advanced tuberculosis."

"Thorn reports that twenty-two physicians out of 339 practicing in Ohio, replied in the affirmative to the question, 'have you been able to trace any cases of tuberculous disease to the milk of unhealthy cows?' and that thirty-three replied in the affirmative to the question, 'Have you had reason to suspect the origin of tubercular disease in older children or adults to be in the meat or milk supply?'

This series of experiments and observations has been selected from literature with the greatest care, any reports which appeared not to be well authenticated or of a doubtful nature being excluded."

"Further circumstantial evidence is at hand in the fact that such large numbers of the bottle fed children die of the abdominal form of tuberculosis, and while, in some countries, the death rate of adults shows a marked decrease, the tuberculosis of children, and especially infants, is on the increase."

As previously stated, if we could but supply the one missing link, viz: whether the bacillus of tuberculosis is pathogenic for man, we would have our chain of evidence complete, and a positive demonstration would be our reward and the question would be no longer doubtful. The cases which I will now quote, from Dr. Repps' report, show conclusively that tuberculosis in the bovine species can be conveyed to man through one channel at least. "Tscherming, of Copenhagen, attended a veterinarian who had cut his finger in making a postmortem on a tuberculous cow. The wound healed but there still remained a swelling which soon ulcerated and refused to heal so that the whole tumefied mass had to be cut out. The microscope revealed the distinct tuberculous process and the presence of the characteristically staining bacilli." Pfeiffer attended at Weimar, a veterinarian named Moses, thirty-four years old, of good constitution and without hereditary disposition, who, in 1885, cut his right thumb deeply in making a postmortem on a tuberculous cow. The wound healed, but six months later the cicatrix still remained swollen and in autumn, 1886, the man had pulmonary tuberculosis with bacilli in his sputa and death occured in two and one-half years after the wound. Post-mortem revealed tuberculosis of the joint of the wounded thumb, and in the lungs extensive tubercles and vomicæ." "Law reports that a young veterinary friend of his who was inoculated in the hand in opening a tuberculous cow, suffered from a tumefaction of the resulting cicatrix with tubercle-bacilli."

Rich reports that a man cut his finger on a spicule of bone, while making a post-mortem examination of tuberculous cows, and that in a few weeks he developed a tuberculous joint, and a few months later showed unmistakable signs of phthisis.

Ravenel reports the case of a veterinarian who cut the knuckle of his finger while making post-mortem examina-

tion of a tuberculous cow. The wound healed badly, remained swollen and showed decided tendency to ulcerate. Removal of cicatricial mass was practiced the tissues sent to him for examination. They showed typical tubercular lesions with giant-cell formation.

"I am well acquainted with this case myself and believe it to be an undoubted case of direct transmission of tuberculosis from cow to man by inoculation. This veterinarian told me that he did not become alarmed about the wound on his finger until he noticed a swelling and tenderness of the lymphatic glands on the muscle of the elbow."

The statistics gathered on this point are not many, but are exceedingly valuable as far as they go.

BOVINE TUBERCLE MORE VIRULENT THAN THE HUMAN VARIETY.

From the scattered records of inoculation experiments, both early and recent, relative to the degree of virulency of of the tubercle bacilli of man and the bovine species, the conclusion arrived at I can best express by the following quotation: "To sum up the matter in a few words, it may be said that bovine tubercle has been shown to be more virulent than the human variety for cattle, sheep, goats and rabbits, while no distinction has been shown in the case of horses, pigs, cats and dogs.

DOMESTIC COW THE NATURAL HARBINGER OF THE BACILLUS TUBERCULOSIS.

Dr. G. A. Johnson, in an article read before the Sioux Valley Medical Association, takes the position that in the bovine species we have the natural hosts of the bacillus tuberculosis. His argument is so fair and altogether unique that while it is entirely foreign to the prevailing idea of the medical fraternity, it is certaiuly worthy of serious consideration. He states his proposition in this way. "Tubercular lesions, wherever found, are the direct results of the action of the tubercular bacillus; and further, that the domestic cow is the natural harbinger of this bacillus; or in other words, tuberculosis was primarily a disease of the bovine species and is found in man and other animals as a result of transmission brought about through the ability of the tubercular bacillus to adapt itself to the various conditions as found in the various animals.

He reasons from analogy that a careful study of the geographical distribution of tuberculosis reveals the fact that all people who use the milk and flesh of the domestic cow (the and inbred cow) as food products are more or less afflicted with tuberculosis, and further, that there is usually a very uniform ratio between the quantities of such foods consumed and the prevalence of the disease among the people.

On the other hand all of those people who do not use the food products of the domestic cow are comparatively free from the disease.

Prof. E. F. Brush, M. D., of Mount Vernon, N. Y., states as follows: "This insidious and delusive disease is not the result of civilization as is supposed. Barbarous and semi-civilized races are afflicted as severely as many of the most advanced civilized races." Neither geographical position nor climatic conditions are a factor in the distribution of pulmonary phthisis. Every known part of the globe, with a few isolated areas excluded, is a habitat of the disease. After several years of close study of the affection and consulting all accessible statistics and the habits of the people where the disease prevails, the only constanly associated factor is found, in my opinion, in the inbred bovine species without any regard to the social position of a community or its geographical habitation, terrestial or atmospheric condition. If a community is closely associated with inbred cattle, tuberculosis is prevalent. In the fifteenth annual report of the State Board of health of New York, is found the following: "Human tuberculosis is co-extensive with bovine tuberculosis. Broad generalization of our laws and knowledge gives a close parallelism between the numbers of dairy cows and the prevalence of tuberculosis in the human race. Countries that have few or no cattle, or in which the herds are mainly kept in the open air, and are therefore largely protected from the disease show, as a rule, little tuberculosis in man."

Dr. G. A. Johnson, in substantiation of his argument, has found the conditions prevailing in different countries relative to this matter as follows:

Europe—Cattle have existed and tuberculosis has prevailed in man for centuries.

Australia—Tuberculosis was so rarely seen in early days as to lead to the idea that the climate was incompatable with the disease, but with the advent of cattle raising con-

sumption appeared among the people and has been gradually increasing.

New Zealand—Among the native Maories phthisis was unknown previous to the settlement of the English, and they possessed no cattle, but since that time tuberculosis has become a veritable scourge. Hirsch has said, "In my opinion the death rate from phthsis will keep on increasing in that locality if the breeding of cattle is not properly regulated by law."

South Africa—The coast tribes of Africa have been inbreeding cattle for centuries, and the natives have been tuberculous, while the tribes in the interior have had no cattle, because of the Tsetse fly which stings and kills them, have always been free from consumption.

Madagascar—The flesh and milk of cattle has been the principle diet of the native and they have been severely afflicted.

North American Indians—The native American Indians were always free from consumption until Uncle Sam began dealing out meat and cattle to them. Their habit of eating any and all parts of the carcas, often without cooking, has aggravated the conditions for the most favorable transmission of the disease and they have become consumptive.

The Esquimaux—Dr. Johnson has well expressed it when he says, "The Esquimaux has his dogs and reindeer, but no tuberculosis, while the indian has his dogs and beef and is seriously afflicted with tuberculosis." On the other hand, it is found that the Indian is no more susceptible to the disease than is the Esquimaux, for when the latter is brought in contact with the white man and his cow he readily contracts the disease, etc.

Italy—The people are tuberculous, notwithstanding they have one of the balmiest climates of the earth.

China—Notwithstanding their dense population, consumption is rare, because the lower classes, which constitute the mass of the population, get very little or no meat or milk. And so he goes on with a review of the different people of various countries and islands of the globe, showing in each and every instance that those people who use the milk or meat of cattle are consumptive and just in proportion as they use said products and those who do not possess cattle at all are entirely free from it.

Climate—Immunity does not exist in any climate, or among any race of people. And while high and dry

climates like Colorado are beneficial in staying the progress of the disease, yet it prevails in various sections from the torrid to the frigid zones.

Altitude—Altitude has nothing to do with the distribution of the disease, for we find it from the sea coast to the regions of the highest mountains. Dr. Johnson says that "certain peoples inhabiting the Dead Sea basin, which is between 100 and 200 feet below the sea level, are free from tuberculosis, whereas it is more or less prevalent among most people inhabiting the mountainous regions of Europe and America."

Civilization—The disease does not follow in the wake of civilization, for some of the savages and semi-civilized races are seriously afflicted.

Density of Popuation—As previously indicated, China and India, two of the most densely populated countries, are comparatively free from tuberculosis, and in many of the rural districts of Europe and America the disease prevails.

Filth and Poor Sanitation—This has nothing to do with the distribution of the disease for we find it all the way from the wigwam to the palace. The fact remains that all these various conditions simply hasten to retard the morbid process, and not one of them can be said to be a constant factor in the distribution of the disease. The old argument of heredity has long ago fallen to the ground and been trampled to the dust, for new cases of consumption are constantly coming to view, where there cannot be traced any hereditary taint.

The only constant factor seems to be the milk and meat of the bovine species, and we certainly consider this argument worthy of serious consideration.

CONCLUSIONS.

1. The position taken by Dr. Koch is of inestimable value, whether right or wrong, as there has been nothing new but this conclusion placed before the medical and veterinary profession during the past decade, and it has aroused everybody from their lethargy and encouraged discussion and experiment as never before.

2. It is unwarrantable to assume that, because of the low virulence of human bacilli for cattle, that the reverse is true. It has been repeatedly shown that bovine bacilli are more virulent than the human. Bovine bacilli being easily transmitted to rabbit, horse, dog, pig and sheep, and in short, to almost every quadruped on which they have been tried, makes it highly improbable that man is not included in the list; and until this is disproven by actual experiment upon the human, it will not be wise to relax prophylactic measures.

3. Dr. Koch has been grossly misrepresented since his London Congress address. He says, among other things, 'I have one word and only one word to say, and that is what I said in London. That word is 'experiment!'" I would send it to my brother practitioners the world over. The time is past when we may be guided with either certainty or profit by statistics. Nothing short of actual dealing with actual conditions will avail. We demonstrated that human tuberculosis was incapable of transmission to cattle. We have now to lend ourselves to the reverse proposition.

"I did not mean to recommend the abandonment of comprehensive and expensive systems of regulation, prevention and inspection that is now in operation.

"We are well on the road to victory over consumption. The final triumph is denied only by those who are unwilling to sacrifice their hobbies and work together to the common end."

PART II.

TUBERCULIN TESTS OF THE COLLEGE HERD.

BY B. C. BUFFUM.

Our investigation of tuberculosis among the cattle belonging to the College is in line with what has been done by other Experiment Stations of prominence which have been doing live stock work. There is nothing startling or new, perhaps, in our findings, but we feel the matter is of much importance to the public. Dealing as it does, directly with our animal wealth and indirectly, perhaps, with the public health, it is well for the Station to give to the people of the state such information as we possess. We are not indulging in personal opinions or theories, but will confine our statements to what we believe are established facts. We believe it is high time that our agricultural communities should accept the situation, and dispassionately and intelligently take such wise action as will advance their own interests and, in all probability, alleviate human suffering as well.

So much has already been done to prevent and partially cure tuberculosis, that there is no longer excuse for allowing the disease unchecked progress either among animals or men. Tubercular consumption is now known to be a preventable disease and, contrary to the general opinion, it has been demonstrated that it is curable in a large per cent of cases or, at least, that the course of the disease may be checked for many years if taken in time and properly managed. It is probably true that there are over ten million people now living in the United States who are doomed to die of this dread disease unless something is speedily done to reduce the present death rate. This may be considered a fair statement of the present status and prevalence of human tuberculosis.

Cattle seem to be more subject to tuberculosis than any other representatives of the animal kingdom, but it is hardly possible to arrive at a correct estimate of the money loss to our agricultural interests from the bacillus tuberculosis. Coupled with these two items is the supposed relation of human and bovine tuberculosis. The disease in man

and in cattle has long been considered identical and in view of the many facts supporting such belief so well presented by Dr. Glover in Part I. of this Bulletin, it is well that everyone should understand the possible danger and take such precautions as will save money loss with stock, and protect against personal contagion. It is reported that Dr. Koch, before the London conference on tuberculosis, expressed the opinion that human and bovine tuberculosis are not due to the same germ. If reports are true, Dr. Koch believes that there is proof that human tuberculosis cannot be transmitted to cattle and, while not demonstrated, he thinks bovine consumption not transmissible to man. Dr. Koch discovered the true cause of tuberculosis and fully demonstrated the germ nature of the disease. He is one of the world's greatest authorities and his opinion should be given much weight. However, scientists are often misquoted and a simple statement of a failure to produce certain expected results in an experiment is twisted into a quotation from an authority, that it is an impossibility to produce the results. Newspaper misquoting and reportorial enlargement of scientists' statements are often mistaken for true science. It opens the way for ridicule and prejudice and does much to retard the acceptance of scientific facts. If Dr. Koch failed to transmit tuberculosis from man to cattle, or if he has discovered differences in the germs from animals and men which led him to doubt the identity of the two forms of the disease, it does not necessarily follow that the expression of this doubt is a statement of fact that there is one form of the disease in cattle and another in man and that they are never transmissible from one to the other. Dr. Koch thought that his lymph or tuberculin was a cure for tuberculosis. It was a wonderful discovery and a most important one, but because it failed to cure human tuberculosis is no reason for rejecting the careful scientific work of the man. The principle of using the toxin or poison produced by a germ to destroy the germ, or its power to live in the sytem, was established by Jenner when he introduced vaccination against small pox and is successfully used as a cure of the disease in diphtheria. One of our state papers (The Eastonville World) takes a sensible view of the present statements of Koch, that he doubts the general infection of man with bovine tuberculosis, and points out the fact that we need not plunge into the use of unsanitary milk, butter and beef because a scientist has expressed such a doubt. Before

PLATE II. COUNTESS LEE—JERSEY COW WITH GENERALIZED TUBERCULOSIS.

Plate III. Section of Left Lung of Diseased Cow Filled with Tubercles and Calcareous Deposit. Spleen of Diseased Cow Showing Large Tubercles on Surface.

leaving this part of the discussion let me state that there has been a large amount of scientific investigation which goes to prove that human tuberculosis can be transmitted to cattle by direct inoculation, and there is little doubt of its transmissibility from animal to animal or from one kind of animal to another.

If Dr. Koch's announcement is true, it is a most important discovery. However, so much evidence has accumulated to prove that men contract bovine tuberculosis that scientists are slow to accept this new theory of Koch's and will not do so without abundant proof.

The following quotations as made by the "Literary Digest" are of interest:

From the Philadelphia Press.

"The chief evidence of the transmission of tuberculosis from cows to human beings has rested on the cases of children. The strongest proof was summed in a report lately made to the British Medical Council that 'The mortality from tuberculosis in early childhood is not decreasing as at other ages, and the opinion that this is due to infection by milk appears well founded."

"Meanwhile, laboratory evidence accumulated that the human and bovine bacillus were not identical in shape, tests or increase. Cattle are relatively unsusceptible to human tuberculosis. It is extremely probable that Dr. Koch has carried this to full proof and developed the difference to be one of species. If, however, tuberculosis cannot furnish bacilli which gives human beings the disease, the cattle bacilli render cattle diseased. Infection once begun infects the entire herd. Unless people chose to eat diseased meat, and drink milk with bovine tubercle containing, as was found in Boston, 810 million germs to the tumbler, tuberculous cattle must continue to be sternly destroyed."

The following from the "Medical News" of New York:

"The belief that bovine tubercle bacillus is incapable of inducing tuberculosis in man is, of course, by no means new. For years there have been advocates of this side of the question. As a matter of fact, there is abundance of clinical evidence which indicates this capacity. Thus, Tscheving, of Copenhagen, in 1888, reported a case in point. The sufferer was a veterinary surgeon who wounded his finger while making an autopsy on a tuberculous cow. Local tuberculosis in the wounded part developed in a short time. Lefevre collected other equally striking examples which would be very difficult of explanation if our present view is incorrect."

The introduction to this report by Dr. Glover gives the above cases and presents abundant reason for suspecting tuberculous cattle. It will take nothing short of absolute proof to convince that bovine tuberculosis is not

dangerous to man. It is to be devoutly hoped that this is so, as it would greatly simplify the problem of ridding both man and cattle of the worst disease with which either is afflicted. Meanwhile, we should not cease using judicious caution and our researches are doubly interesting. The evidence against bovine tuberculosis has been sufficient excuse for all the laws and regulations enforced against it.

At the close of the British Congress on tuberculosis, before which Professor Koch delivered his paper, a series of resolutions were adopted, among which appears the following, as published in Science, Aug. 1901:

"That in the opinion of this Congress and in the light of the work that has been presented at its sittings, medical officers of health should continue to use all the powers at their disposal and relax no effort to prevent the spread of tuberculosis by milk and meat."

"That in view of the doubts thrown on the identity of human and bovine tuberculosis it is expedient that the government be approached and requested to institute an immediate inquiry into this question which is of vital importance to the public health and of great consequence to the agricultural industry."

There were over 2,500 members at this Congress including many of the world's foremost scientists.

THE TUBERCULIN TEST.

Within the past year the restrictions of this government on the importation of tuberculous cattle has given rise to vigorous protests on the part of men actuated by selfish interests. Our own people submitted to like restriction without complaint, but enforcing such regulations against Canadian cattle has given rise to what we believe are unwarranted attacks on the reliability of the tuberculin test which is used to determine whether or not cattle are tuberculous.

We think it unfortunate that some of our leading stock journals have published attacks on the test, which are calculated to mislead the public in regard to its efficiency and value. The highest authorities state that tuberculin is perfectly harmless to healthy cattle when properly administered as a test for tuberculosis. They are also agreed that it is a means of detecting the disease which is of great value and sufficiently accurate to be practically infallible. Because it gives fever to diseased animals or occasionally fails to produce its effect on such advanced cases that the disease can be found by physical examination does not seem sufficient

reason for condemning it as a diagnostic agent. It is believed that it does not fail to detect the disease in more than one-fifth of one per cent. of cases which are not far advanced in their course, and in our experience the disease has been found in every case which responded to the test.

Tuberculin is a glycerine extract of the toxin produced by the bacillus tuberculosis, but it contains no living germs which can communicate the disease. The normal temperature of an animal is obtained, then a small quantity of the tuberculin is injected hypodermically so it will be absorbed into the blood. If the animal is diseased the tuberculin causes a rise in temperature of 2 degrees or more in 8 to 16 hours, and sometimes a swelling and soreness where the injection was made. It should be used under the direction of a veterinarian or physician, or someone who has used and understands the method of applying the tuberculin and observing the results.

WHY WE TESTED THE COLLEGE HERD.

Our cattle had not been tested and we suspected the disease. However, we had only one animal under suspicion, and we hoped she would be the only case. Gildana, a Jersey cow about eight years old had been out of health for some months. She had the malignant catarrhal fever which was prevalent during the fall months, and did not recover as did other animals which were affected. She seemed to be passing into decrepid old age which we thought due in all probability to tuberculosis. Dr. Glover was consulted and he agreed to test the dairy herd. We did not expect to find many cases as we thought there was reason to believe that tuberculosis might not be so prevalent in our dry sunny climate as it had proved to be in more humid regions. There may have been a little personal pride in the thought that our cattle, which had been given the best of care under the most favorable conditions, would be unusually healthy. As we will show later this idea was not without some foundation in fact. But tuberculosis is a disease which leaves its victim hopeful and in good cheer and one about which the novice should not jump at conclusions. We guessed that Gildana had tuberculosis, but we guessed wrong, for she did not respond to the test and is now believed to be healthy, while other cows in the herd which to all appearances were healthy, were found to be veritable pest houses of infection.

Again, because cattle form so large a part of human food; because they are subject to many diseases fatal to

man, and because cattle products, as milk and butter, are used in the raw state they are a constant menace to the public health. It is important then that the greatest care and sanitary precautions should be used in handling cattle and their products. Outside of the danger to man there is the item of financial loss from the presence and spread of disease among our stock. These are sufficient reasons for every cattle owner applying every test and attention which will insure keeping only healthy stock. Dr. Bang, the great Danish authority, has succeeded in having laws passed which makes sanitary precautions compulsory in Scandinavia, and already enough has been done in Europe to show that tuberculosis may be materially decreased by proper sanitary control of tuberculous subjects among both animals and man. In Denmark national laws make it compulsory to heat all milk to 185 degrees F. before it is sold, or before butter is made from it.

In Germany tuberculous persons are required to take the sanitary treatment prescribed and they find that tuberculosis is decreasing under these laws. Many of our states have legislative regulations for stamping out tuberculosis among cattle, and some of them are extreme in requiring the slaughter of all reacting animals. If human and bovine tuberculosis prove to be the same disease, it would seem that this method would be the surest and quickest way of removing the greatest of all dangers to human life, but because of the uncertainly, we are probably not ready at the present time to adopt such drastic and expensive measures. However, enough is known at the present time so no one is excusable for using milk or butter from cows which have not been given a bill of health and demonstrated free from tubercle, and no stockman is excusable for harboring and breeding the disease in his herd.

RESULTS OF THE TESTS.

Three tests have been made of the cattle on the College farm, by Dr. Geo. H. Glover, veterinarian. The first on December 8, 1900, was of all the cows being milked in the dairy, consisting of seven Jerseys and one Shorthorn and also one Shorthorn which had lost her calf and had not been doing well for some time. Table I gives the result of this test, showing the normal temperatures determined before inoculation and the rise in temperature after injection. The maximum temperatures and total rise of reacting ani-

mals are shown in bold faced type. Unless the rise in temperature was more than 2.5 degrees it was not considered proof of infection. It will be seen that of the nine animals tested five, or 56.6 per cent. reacted.

TABLE I.

TUBERCULIN TEST MADE DEC. 8, 1900.

COLORADO AGRICULTURAL COLLEGE.

No.	Name	Breed	Wt. lbs.	Age yrs.	Nrm'l Temp.	Max'm Temp.	Hours after injec'n	Rise in Temp.	Remarks
					° F	° F		° F	
1	Young Grannie	Jersey	1072	10	100.1	101.5	11	1.4	
2	King Lee Noble	"	1122	4	100.7	**107.1**	11	**6.4**	Destroyed. Early stages of disease
3	Gildana	"	920	10	100.3	101.2	13	0.9	
4	Kate	"	828	4	100.9	**106.7**	11	**5.8**	Destroyed Had generalized tuberculosis
5	Lucy	"	860	4	101.0	**104.9**	11	**3.9**	Destroyed. Disease not advanced.
6	Lelia Rose	"	770	2	101.3	**105.0**	12	**3.7**	
7	Gildana 2nd	"	872	3	101.4	101.8	21	0.4	
8	Orchard Girl	Shorth'rn	1376	5	100.9	102.2	8	1.3	
9	Ambrosia 2nd	"	982	3	101.7	**106.0**	8	**4.3**	Destroyed. Generalized tuberculosis

The second test, principally of the Shorthorn cattle was made January 12. The results are given in Table II. No. 1, Young Grannie; No. 2, Lee Noble; No. 3, Gildana; No. 6, Lelia Rose; No. 7, Gildana 2d, and No. 11, Ambrosia, were cows which were injected during the first test. An interesting point and one which has been urged against the test is that the Jersey, Lelia Rose, and the Shorthorn, Ambrosia, which gave reactions at the first test on December 8, failed to react to this second injection of tuberculin. It merely illustrates the fact that an injection of tuberculin renders an animal immune to the test for some time after it has been made.

The time between tests of the same animal should probably not be less than six months, and the results of a test should not be accepted unless it is known that the animals have not been injected with tuberculin for at least six months time. Therefore we did not accept the failure to react at this second test as an indication of freedom from the disease and at the post mortem Ambrosia proved to be about as bad a case as could exist and the animal continue to live, although she appeared fairly well and thrifty.

Counting out the animals tested December 8, including

TABLE II.

TUBERCULIN TEST MADE JAN. 12, 1901.

COLORADO AGRICULTURAL COLLEGE.

No.	Breed	Wt.	Age	Nrm'l Temp.	Max'm Temp.	Hours ofter injec'n	Rise in Temp.	Remarks
1	Jersey	1072	10	100.8	101.9	12	1.1	Second test
2	"	1122	8	101.4	**106.5**	18	**5.1**	Destroyed. Had generalized tuberculosis
3	"	920	10	100.8	101.3	5	0.5	Second test
4	Shorth'rn	900*	2	102.2	103.3	9	1.1	
5	"	1140	5	101.7	101.2	9	....	
6	Jersey	770	2	101.1	103.0	11	1.9	Second test
7	"	872	3	101.8	101.9	5	0.1	Second test
8	Shorth'rn	1225*	3	102.1	104.0	13	1.9	
9	"	1240*	3	103.2	102.3	5	....	
10	"	1260	3	102.4	**106.3**	13	**3.9**	
11	"	1250*	3	102.8	102.2	21	....	Second test. Generalized tuberculosis
12	"	1050	3	102.2	**106.1**	13	**3.9**	
13	"	1190	7	102.4	102.3	9	....	
14	"	1075	7	102.4	102.9	4	0.5	
15	"	1320	4	102.6	102.9	4	0.3	
16	"	1135	5	101.8	102.3	9	0.5	
17	"	1300*	4	102.7	102.5	4	....	
18	"	1225	5	102.2	102.7	4	0.5	
19	"	1275*	4	102.2	**105.8**	15	**3.6**	
20	"	1650	2	102.5	**106.5**	15	**4.0**	
21	Jersey	800	1	101.6	103.0	12	1.4	
22	"	805	1	101.8	103.6	10	1.8	

* Estimates based on later weights.

TABLE III.

TUBERCULIN TEST MADE JAN. 26, 1901.

COLORADO AGRICULTURAL COLLEGE.

No.	Breed	Wt.	Age	Nrm'l Temp.	Max'm Temp.	Hours after injec'n	Rise in Temp.	Remarks
1	Jersey	1540*	3	100.8	101.7	8	0.9	Bull
2	Shorth'rn	1000*	2	101.9	101.0	11	....	
3	"	1260	2	101.8	101.3	8	....	
4	"	1270	12	102.5	103.9	21	1.4	
5	"	1565	6	103.6	105.6	13	2.0	

those which reacted, there were 18 new ones tested January 12. Of the 18 animals, four, or 22 per cent. reacted. This does not include No. 8 which gave a temperature rise of 2 degrees.

While we had taken the temperatures of all the cattle, not quite enough tuberculin was obtained so a third test was made January 26. One Jersey bull and four cows were tested. (See Table III.) As none gave a rise of temperature of more than 2 degrees it was not considered sufficient to prove the disease in any of them.

SUMMARY OF REACTIONS.

A total of 31 head were injected with tuberculin and 10 reacted, or thirty-two and one-fourth per cent. There were 11 Jerseys, of which 5 reacted, or nearly 45.5 per cent. Out of 20 Shorthorns, 5 gave definite reactions, or 25 per cent., and 2 doubtful cases in which the temperature did not rise high enough to be considered proof of disease.

There were in reality two herds of Shorthorns. The old herd which had been raised on the College farm or had been here for 8 or 9 years did not contain a diseased animal while the 5 cases were out of a herd of 12 animals which had been brought from Iowa one year before the test. Then there was 41⅔ per cent. of the Eastern Shorthorns and none of the Western animals tuberculous. While this may have been an accident, we take it as significant, and probably it indicates what may be expected in a general way. It is generally believed that Western range cattle are practically free from tuberculosis.

POST MORTEMS.

Four of the reacting Jerseys and one Shorthorn have been killed and carefully examined. These examinations were conducted by Dr. Glover. In order to make the examinations as thorough and authentic as possible Dr. Glover secured the assistance and cooperation of Dr. L. Clark, a veterinarian of long standing and ability in the government employ, and Dr. R. McCarroll of Fort Collins. Mr. C. J. Griffith and the writer assisted with the work and took the notes. The College authorities were present to satisfy themselves that the disease was demonstrated and the class in veterinary science took an interested part. None of the cows had the disease far enough advanced to make it possible for the veterinarians to detect it by physical examina-

tion, but the diagnosis as made by the use of the tuberculin proved correct in every case and three of the five cows examined had generalized tuberculosis, i. e., nearly all the organs were diseased. In three of the four Jerseys examined tubercles were found in the udder where they were discharging into the milk. No attempt will be made to write a technical description of these post mortem examinations, but the following general notes will give the reader an idea of the amount of infection demonstrated:

Kate. (No. 4 in Table I.) Jersey cow, 4 years old. Reaction, 5.8 degrees. Killed and examined December 15, 1900. Carefully examined before death, but could find no evidence of disease. Cow in good condition with considerable internal fat. Had been lame and evidently suffering from effect of the injection of tuberculin since December 8. Lungs healthy except the lymphatic glands in the lungs which were hard and gritty with calcareous deposits in the tubercles. Kidney healthy, scattering tubercles size of pinhead to one-half pea, scattered over the intestines, especially the large intestine. Spleen covered with tuberculous growths. Liver with scattering tubercles and grit of small size all over surface and through the mass. Inside of womb and placenta along with umbilical cord covered with tubercles from size of grain of sand to small pea. Small tubercles found in udder. Photographs taken of cow and affected glands Carcass burned.

King's Lee Noble. (No. 2 in Table I.) Jersey cow, four years old. Reaction, 6.4 degrees. Killed and examined December 29, 1900. Apparently in good health. Glands in lungs and those from the mesenteries affected, but not in advanced stage of disease. Well developed tubercles in the udder where milk glands were discharging over them. Photographs taken of cow before death, and of affected glands. Carcass burned

Lucy. (No. 5 in Table I.) Jersey cow, four years old. Reaction, 3.9 degrees. Killed and examined December 29, 1900. Cow apparently healthy. All organs apparently healthy, Finally small glands from the mesenteries were found with well developod tubercles in the milliary stage. (Millet-seed like excretions of calcareous matter encysted in the glands.) Photographs taken before and after death, also of glands. Carcass burned.

Lee Noble. (No. 2 in Table II.) Jersey cow, seven years old. Reaction, 5.1 degrees. Killed and examined January 26, 1901. Though this cow was apparently healthy, inside of carcass and organs were found to be literally covered and filled with tubercles, the principal affection being in the liver, lungs, udder, lymphatic glands, placenta and umbilical cord. Hard, gritty, calcareous deposits everywhere. Carcass burned.

Ambrosia. (No. 9 in Table I and No 11 in Table II.) Shorthorn cow, three years old. Reaction, 4.3 degrees. Killed and examined May 4, 1901. Cow apparently in good condition, well supplied with fat and with no external evidence of the disease. She had not been eating well for some time and we had been unable to get her with calf. Had a small tumor on right jaw. Post mortem demonstrated an advanced stage of tuberculosis. Ovaries and uterus badly diseased and filled with pus from the breaking down tubercles. Beside the sex organs, the spleen, liver and intestines,

along with lining of lungs and heart, were covered with surface tubercles. The lungs were very much affected, the left one being almost entirely filled with tubercles and calcareous deposits. Those who saw this dissection expressed surprise that the cow could be so generally diseased and continue to live, while in reality she had evidenced little outward sign of trouble. Photographs taken of spleen, glands and uterus. Carcass burned.

REACTING ANIMALS NOT ALL DESTROYED.

It may be well to explain why all reacting animals were not destroyed at once. Some of them were kept for several reasons. In the first place it is a matter of some interest to determine whether tuberculous animals from the East will be cured of the disease by open air treatment when brought West. Second, it is considered possible to raise healthy calves from cows which are not badly affected, by separating them from the mother at once and putting them on nurse cows which are free from disease. Third, the cows will be useful clinical material for the instruction of students in veterinary science. The reacting animals are being kept away from healthy ones and as soon as our barn is remodeled and thoroughly disinfected we hope never to put a tuberculous animal in it. With every precaution against spreading infection the cattle will be handled for a time for experimental purposes. At the same time we will speed the day when we can say that our stock is free from disease and that there is no hereditary tuberculosis or tendency to it in any cattle at the College.

CONCLUSIONS AND RECOMMENDATIONS.

1. While there is probably less disease in Colorado than among cattle from humid states, the disease is present in our herds and should receive attention.

2. Stockmen, especially dairymen and owners of family cows should get rid of the disease and not introduce more of it by the purchase of infected animals.

3. The tuberculin test is a reliable way of finding out whether cows are free from tuberculosis.

4. People should secure sanitary milk and disease-free butter, especially where children consume them. Milk or cream not from tested cows should be boiled before using. In ordinary practice any heat less than boiling should not be considered sufficient to kill the germs.

5. We do not know whether tuberculosis is commonly transmitted from cattle to man. The evidence that it is, as

presented in Part I of this bulletin is very strong. On the other hand so great an authority as Dr. Robert Koch thinks he has proved that human and bovine tuberculosis are different diseases.

6. In the state of our present knowledge of tuberculosis we can afford to take no chances by harboring infected animals, both because of the danger to ourselves and of the loss among our stock.

7. A cow may be seriously diseased so she will spread the infection to her calf or the rest of the herd and finally become unproductive and worthless herself without showing external signs of having a disease. The only known way of proving a cow healthy is by using the tuberculin test.

8. There is evidence to show that calves may inherit tuberculosis from their mothers, but it is generally considered that they are free from the disease when born and may be kept healthy by raising them on milk which is free from the bacilli.

9. Where apparently healthy cows which respond to the test are kept for raising calves they should be isolated and every precaution taken to prevent the spread of the disease to the rest of the herd. We found the sexual organs badly diseased in three out of five cows examined and do not think it would be safe to use the herd bull with them. In the writer's opinion the most profitable method is complete and conscientious destruction of diseased animals.

10. Cow stables should be regularly cleansed and disinfected. Good disinfectants are chloride of lime or a wash of equal parts carbolic acid and sulphuric acid mixed and diluted with twenty parts water. Sulphuric acid must be added slowly and carefully to the carbolic acid and these carefully to the water.

Bulletin 67. December, 1901.

The Agricultural Experiment Station

OF THE

Agricultural College of Colorado.

THE DISTRIBUTION OF WATER

POWERS AND DUTIES OF IRRIGATION OFFICIALS IN COLORADO

BY

H. N. HAYNES.

PUBLISHED BY THE EXPERIMENT STATION
Fort Collins, Colorado.

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1. *The State Engineer.*
   Appointed by the Governor for a term of two years.

   2. *Superintendents of Irrigation.*
      One to each of the six water divisions. Subordinate to the State Engineer. Superior to the Water Commissioners. Appointed by the Governor, term of two years.

      3. *The Water Commissioners.*
         One to each water district. Subordinate to Water Superintendent and to the State Engineer. Appointed by the Governor from persons recommended by the several Boards of County Commissioners in the counties in which the water districts extend; term of two years.

The water districts consist of "the land now irrigated or which may be hereafter irrigated from ditches taking water from the following described rivers or natural streams of the State of Colorado."

WATER DIVISIONS AND DISTRICTS.

1. *The Platte, or Water Division No. 1.* Consists of all the water districts consisting of lands irrigated from the North and South Platte, Big Laramie River, North and Middle Forks of the Republican, Sandy and Frenchman Creeks and tributaries.

Water Districts. 16 in number. Nos. 64, 1, 28, 23 on the South Platte numbering from the State line; 3 on the Cache la Poudre; 4 Big Thompson; 5 St. Vrain; 6 Boulder and Coal Creeks; 9 Bear Creek; 46 and 47 North Platte (North Park); 48 Big Laramie; 65 Republican, Sandy and Frenchman Creeks.

2. *The Arkansas, or Water Division No. 2.* Consists of water districts of lands irrigated from the Arkansas River and its tributaries, Smoky Hill, South Fork of the Republican and Dry Cimarron.

Water Districts. 13 in number. Nos. 11, 12, 14, 17 and 67 on the Arkansas, in order down stream; 10 Fountain Creek and tributaries; 13 Grape Creek; 15 St. Charles; 16 Huerfano; 18 Apishapa; 19 Purgatoire; 49 South Fork of the Republican and Smoky Hill; 66 Dry Cimarron.

3. *The Rio Grande, or Water Division No. 3.* Lands watered from the Rio Grande and its tributaries.

Water Districts. (8). Nos. 20 and 24 Rio Grande; 21 Alamosa and La Jara Creeks; 22 Conejos; 23 Rio Grande and Costilla; 25 San Luis, Sand or Medano, Big and Little Spring Creeks; 26 Saguache; 27 Tuttle, Carnero and La Garita; 35 Trinchera.

4. *The San Juan, or Water Division No. 4.* Lands irrigated by San Juan River and its tributaries.

Water Districts. (6). Nos. 29 and 32 San Juan; 30 Rio Las Animas; 31 Los Pinos; 33 La Plata; 34 Rio Mancos.

5. *Grand River, or Water Division No. 5.* Lands in Colorado irrigated by the Grand River and its tributaries.

Water Districts. (20). Nos. 28, 39, 42, 45, 51, 53, Grand River; 36 Blue River; 37 Eagle; 38 Roaring Fork; 39 Grand, Elk, Rifle and Rhone; 40 Crystal Creek, Smith's Fork and Gunnison; 41 and 68 Uncompahgre; 42 Grand, Gunnison in Mesa County; 50 Muddy and Troublesome Creeks; 59 Gunnison; 60 San Miguel; 61 and 63 Dolores; 62 Gunnison.

6. *Green River, or Water Division No. 6.* Lands irrigated bv water taken from the Green River and its tributaries.

Water Districts. (7). Nos. 43 White River; 44, 55, 51 and 58 Yampa; 54 Little Snake; 56 Green River.

INTRODUCTORY.

Every person who uses water in Colorado, whether for agricultural or domestic purposes is affected by the methods of distribution of the state, or by their application.

At least two sets of administrative machinery are required to deliver water to the consumer; one under the direction of the state officials provides for the division of water from the streams to the ditches and the protection of their various rights; the other, for the carriage and distribution of water from the head gates of the ditches to the consumer.

The machinery of the state is more particularly the subject of this bulletin. The methods of distribution to be followed by the ditches, and the duties of the ditch officials, are left to the ditches themselves. These are generally provided for in the by-laws of the ditches, or by custom. It is hoped to take up the division in ditches more fully in a future bulletin.

This bulletin consists of two lectures given by Hon. H. N. Haynes of Greeley, before the Short Course for Irrigation Officials, given at the Agricultural College in the spring of 1901. Their importance concerning one of the subjects which touches closely on the agricultural welfare of Colorado justifies a wider distribution.

They give a summary useful to every consumer and to the officials themselves on the powers and duties of the State Irrigation Officials, and aside from the intrinsic importance and the value of the views of a careful legal student, the information is widely scattered and difficult of access.

To those who have been acquainted with the development of Colorado irrigation law, Mr. Haynes needs no introduction. To others, it is sufficient to say that he was one of the first to represent the state as judicial referee in decrees relating to the appropriation to ditches. In the subsequent development of Colorado law on irrigation he has been actively concerned in the settlement of almost every question of importance brought for judicial determination in Northern Colorado; and a student of irrigation law in its broader aspects.

L. G. CARPENTER, Director.

THE DISTRIBUTION OF WATER

POWERS AND DUTIES OF IRRIGATION OFFICIALS UNDER COLORADO LAWS.

By H. N. HAYNES.

It is the purpose of this paper to consider the powers and duties of state officials in distributing water. The American law of irrigation is yet in a formative state. It was unknown to the common law of England, from which we have borrowed the great body of our system of jurisprudence. It has been gradually building as the result of customs of the early settlers in the arid part of the United States, judicial decisions announced thereon, and the enactment of statutes, both by Congress and the several Territorial and State governments. Most of the decisions of the courts on irrigation subjects up to this time, have pertained to questions of appropriation of water from running streams, and from other sources of supply, and to controversies between rival ditch owners as to their relative rights, while comparatively little attention has been given to the matters now under consideration. So noticeable is the dearth of judicial decisions on the question of distribution of water by officials in charge, that in the two text-books on irrigation law, written respectively by Mr. Kinney and Mr. Long, the space devoted to the subject occupies but a very small fraction of the volumes.

In Long on Irrigation, which is divided into 15 chapters, but one chapter, the 12th, containing only four sections, is on the subject of public control of irrigation, and that chapter consists in the main of references to statute law. The space devoted to the same subject in Kinney on Irrigation, is about as limited.

It follows from the foregoing that little more can be said on the subject of the duties of the several water officials than to call attention to the statutes of the state prescribing their duties, to make some comments thereon with reference to practical questions likely to arise, to indicate the probable position which may be taken by the courts, and to suggest what line of policy and action should guide the officials under the statutes, to carry out their true intent and purpose, and so far as possible, to obviate the necessity of contentions and unnecessary litigation. It can readily be seen, it is difficult to go very far into this discussion

without traveling into ground which is somewhat open to controversy. The lack of authoritative judicial decisions on many questions likely to arise, is necessarily a source of embarrassment in making such comments from a professional standpoint.

EARLY LEGISLATION.

It is interesting to note that the first Legislature of Colorado Territory, on November 6, 1861, passed an act to protect and regulate the irrigation of lands, the fourth section of which, down to the proviso, reads as follows:

> "That in case the volume of water in the stream or river, shall not be sufficient to supply the continual wants of the entire country through which it passes, then the nearest justice of the peace shall appoint three commissioners as hereinafter provided, whose duty it shall be to apportion in just and equitable proportion, a certain amount of said water upon certain or alternate weekly days to different localities, as they may in their judgment, think best for the interests of all parties concerned, and with a due regard to the legal rights of all."

The proviso of the section excepted from its operation land on what is known as Hardscrabble Creek, a tributary of the Arkansas. In the Revised Statutes of 1868, the same section was re-enacted, except that the Probate Judge was made the official to appoint the three commissioners, instead of the nearest Justice of the Peace. In 1870, by act approved February 11th of that year, that portion of said section 4, which referred to Hardscrabble Creek, was repealed. (Session Laws, 1870, p. 158, Sec. 1.)

In 1872, there was further legislation concerning the duties of the water commissioners in the County of El Paso. It was provided that they should receive $5.00 per day when discharging their duties, to be paid by means of a tax levied by the County Commissioners, on each person using water for irrigation, in proportion to the amount of water used by each person.

In the second section of the act approved February 6, 1872, concerning irrigation in El Paso County, it was provided that the commissioners, with a due regard to prior vested rights, should establish such rules and regulations as in their judgment are necessary and proper to secure the purposes of the act, and to control the use of water for irrigation.

The third section of the act made it a misdemeanor subject to a fine and imprisonment, for a person to use water from any ditch or water course of the county to which he was not entitled, when the commissioners were controlling the same, or to hinder any commissioner in the performance of his duties.

A statute adopted February 9, 1872, applicable only to Pueblo County, required each ditch company to construct a tail ditch to return water with as little waste as possible, to the river, and made it unlawful to take more water into a ditch than was

necessary to irrigate the land under it when water was scarce in the stream. The second section amended the act of 1868, by substituting one commissioner for three commissioners. The third section required in Pueblo County, before a commissioner should be appointed by the Probate Judge, that a majority of the riparian owners on each stream, should sign a petition, requesting an appointment to be made, mentioning whom they preferred. (Session Laws, 1872, p. 144.)

The General Laws of 1877, which was a compilation of previous general statutes, as well as of those enacted by the first general assembly of the State of Colorado, contained the fourth section of the chapter concerning irrigation in the Revised Statute of 1868 without change, except that the words County Judge were substituted for the words Probate Judge. The compiler of the General Laws evidently overlooked the amendment of 1870, repealing the Hardscrabble proviso.

In the compilation known as the General Statutes of 1883, this important section of early Colorado law is printed with the amendment made in 1870, as Section 1714 thereof. It reads as follows:

"In case the volume of water in said stream or river shall not be sufficient to supply the continual wants of the entire county through which it passes, then the County Judge of the county shall appoint three commissioners as hereinafter provided, whose duty it shall be to apportion in a just and equitable proportion, a certain amount of water upon certain or alternate weekly days to different localities, as they may in their judgment, think best for the interest of all parties concerned, and with a due regard to the legal rights of all."

The same section was again printed in 1890 as Section 2259, of Mills Annotated Statutes.

Just how far any part of this old statute can be considered as now in force, may be a somewhat open question. Certainly the act of 1879, providing for the appointment of one water commissioner for each water district, constitutes an implied repeal of the power of the County Judge to appoint three commissioners; but whether the courts will or will not hold that the power "to apportion in a just and equitable proportion, a certain amount of water upon certain or alternate weekly days to different localities, as the commissioner may in his judgment think best for the interests of all parties concerned, and with a due regard to the legal rights of all," still vests in the water commissioner of the district, may be fairly debatable.

Further on we will consider this subject of apportioning water in time to different localities under the discretionary powers of the water commissioner, without reference to this statute. From any point of view, it is interesting to note that there has been legislative recognition of the wisdom of such alternate supply under certain circumstances of scarcity.

Prior to the year 1879, the system of dividing the water of running streams among the different ditches entitled thereto, was extremely crude. There had been no provision made to determine judicially or otherwise, except in the discretion of the commissioners, to how much water each ditch was entitled.

LEGISLATION NOW IN FORCE.

In 1879 the present Colorado system of adjudicating priorities and providing for the enforcement thereof, had its inception. It was attempted in that year, by the second general assembly, to provide a system of procedure to adjudicate priorities, but that part of the act of 1879 was found defective, and amended in 1881. In the act of 1879 ten irrigation districts were created, and it was provided that others might be created by the Governor, on petition of parties interested. Subsequent legislation has created new districts so there are now 69. The sixteenth section of the act provided for the appointment of one commissioner for each district, and the method of his appointment.

WATER COMMISSIONERS.

POWERS AND DUTIES UNDER THE STATUTES.

The 18th section of the act of 1879 (Section 2384 of Mills Annotated Statutes) defined the duties of the water commissioner as follows:

> "It shall be the duty of said water commissioner to divide the water in the natural stream or streams of their districts among the several ditches taking water from the same, according to the prior rights of each respectively; in whole or in part to shut and fasten, or cause to be shut and fastened, by order given to any sworn assistant, sheriff or constable of the county in which the head of such ditch is situated, the head gates of any ditch or ditches heading in any of the natural streams of the district, which in a time of scarcity of water, shall not be entitled to water by reason of the priority of the rights of others below them on the same stream."

In 1887, Superintendents of Irrigation were provided for and their duties prescribed. The 5th section of the act (Sec. 2451, M A. S.), reads as follows:

> "Each water commissioner shall report immediately to the superintendent of irrigation of his division, when he is called out, and when he ceases to be needed, and shall, during the continuance of his duties, be under the control of the superintendent of irrigation of his division."

The 8th section of the same act (Sec. 2454, M. A. S.), reads as follows:

"Said superintendent of irrigation shall have the right to call out any water commissioner of any water district within his division. at any time he may deem it necessary, and he shall have the power to perform the regular duties of water commissioner in all the districts within his division."

In the 9th section of the same act (Sec. 2455, M. A. S.), each water commissioner is required to make reports to the superintendent of irrigation as often as required by him. Such reports of a water commissioner must contain information concerning,

(a) The amount of water needed to supply all ditches and reservoirs in his district, meaning of course, under each stream in the district.

(b) The amount of water coming into the district to supply such needs.

(c) Whether the water supply is on the increase or decrease.

(d) What ditches or reservoirs are, at the time of the report, inadequately supplied.

(e) The probability concerning the supply prior to the next report.

(f) Such other and further information as the superintendent of irrigation of that division may suggest.

Printed blank forms prepared by Superintendent of Irrigation would be helpful in the matter of such reports.

The 10th section of the same act of 1887 (Sec. 2456, M. A. S.) pertains in part to the duties of the water commissioners. It provides, in substance, that when any ditch or reservoir is not receiving its regular water supply, its owner may report such fact to the water commissioner of his district, who shall, if practicable, apportion the water in his district to aid the ditch mentioned, if he can do so, and shall, if necessary, by telegram report the situation to the superintendent of irrigation, to enable that official, if necessary and practicable, to supply the needed water at the expense of junior appropriators from some other district.

In 1889 an act was passed, the first section of which (Sec. 2293, M. A. S.) requires any person or corporation diverting water from a public stream, to erect and maintain headgates and waste gates in connection with his ditch, and provides that after five days' notice so to do by the water commissioner of the district or by the state engineer, if such headgates are not erected, then the same shall be constructed by the water commisisoner, who is also vested with power to recover the expense thereof from the delinquent ditch owner.

The second section of the same act (Sec. 2294, M. A. S.) contains similar provisions, with reference to the keeping of suitable locks and fastenings on headgates where water is taken from a public stream, and on failure of the owner so to do, it is made the duty of the water commissioner to provide suitable locks and fastenings, and collect the cost thereof from the ditch owner.

By another act adopted in 1889, many important new duties and powers were thrown upon water commissioners. By its first section (Sec. 2386, M. A. S.), a water commissioner in discharging his duties is vested with the power of a constable, and is authorized to arrest any person violating his orders relative to the opening or shutting down of headgates, or the using of water for irrigation purposes, and to cause the offender to be prosecuted before a Justice of the Peace.

In a proviso to the same section, the orders of the superintendent of irrigation and of the state engineer shall be treated as superior to those of the water commissioner.

By the 3rd section of the same act (Sec. 2388, M. A. S.), the water commissioner is given power to employ a suitable assistant or assistants to aid him in discharging his duties. Such assistants are to take the same oath as the water commissioner, and to obey his instructions.

The 5th section of the same act (2391, M. A. S.), being a very important one, is here quoted in full, as follows:

> "It is hereby made the duty of the water commissioner, after being called upon to distribute water, to devote his entire time to the discharge of his duties when such duties are required, so long as the necessity of irrigation in his district shall require; and it is made his duty to be actively employed on the line of the stream or streams in his water district, supervising and directing the putting in of headgates, waste-gates, keeping the stream clear of unnecessary dams or other obstructions, and such other duties as pertain to a guard of the public streams in his water district; and for willful neglect of his duty he shall be liable to fifty dollars fine, with costs of suit."

The 6th section of the same act (Sec. 2392, M. A. S.) provides that the water commissioner shall not begin his work until called on by two or more owners or managers or persons controlling ditches in his district, by written application, stating necessity for their action; it is also provided that the water commissioner shall cease to perform his duties when the necessity therefor shall cease.

In the same year, 1889, another act was passed imposing a penalty for the bribing of persons in charge of the distribution of water. This section (Sec. 2398, M. A. S.) makes it a misdemeanor for any water commissioner or his assistant to take or receive any money, promises or favors, or anything of value intended to influence him dishonestly to favor any person in the distribution of water to the injury of others.

In 1895 another statute was passed providing for the regulation of the use of the waters of the state. The same, consisting of three sections, is printed in the third, or supplemental volume of M. A. S., as sections 2384a, 2388a, and 2384b.

By the 1st section of the act (Sec. 2384a, Mills' Sup.), each water commissioner is empowered, and it is made his duty on

application of the owners of one or more ditches in his district, immediately to make or cause to be made, a thorough examination of all ditches within his district, to ascertain what use is being made by the consumers thereunder. If he ascertains that any ditch owner is permitting any water flowing in his ditch to be wasted, or to be wastefully, extravagantly or wrongfully used by its consumers, or put to any other use than that to which it is entitled to be used in its priority order, when needed by others, it is made the duty of the water commissioner immediately to shut off the supply of water in such ditch, to such an extent as in his judgment water was wasted, or wastefully, extravagantly or wrongfully used.

The 2nd section of the act (Sec. 2388a, Mills' Sup.) authorizes the water commissioner to appoint not to exceed two deputies to speedily make the examination provided for in section 1, just mentioned.

The 3rd section of the act (Sec. 2384b, Mills' Sup.) makes it a misdemeanor for any water commissioner to fail to perform the duties mentioned.

This act is one of special importance, increasing both the powers and duties of the water commissioners, and if properly executed will be of great benefit.

In 1897 an act was passed to regulate the exchange of water between reservoirs and ditches and the public streams, whereby, among other things, it was made the duty of any person or company transferring water from one public stream to another, to construct and maintain under the direction of the state engineer, measuring flumes or weirs, and self-registering devices, where the water leaves its natural watershed, and is turned into another, and also where it is finally diverted for use from the public stream.

The 3rd section makes it the duty of the water commissioner of the district where the water is used, to keep a record of the water so turned into his district from another.

The 4th section contains similar provisions as to delivering water to a public stream from a reservoir, so that the owner of the reservoir may take an equivalent amount higher up the stream in exchange. The section requires the water commissioner to determine and regulate this matter of exchange.

In 1899, by an act in relation to irrigation, a system of procedure in court is provided, in case a permanent change of the point of diversion of an appropriation is desired, to enable the court to determine whether the proposed change will be injurious to juniors or not. When a decree is entered in such a cause, a certified copy thereof is to be delivered to the state engineer, and that official thereupon issues a notice to the water commissioner of the district affected, notifying him of the

change made. Thereupon the water commissioner is required to allot the priority right to the new ditch, in pursuance of the new decree.

The 3rd section of the same act, permitting between ditch owners an exchange of water for a limited time to save crops, or to use the water more economically, provides for the owners making such loan or exchange, to give notice concerning the same, and thereupon requires the water commissioner to recognize the exchange in distributing the water.

No legislation of the Thirteenth General Assembly which has recently adjourned, affecting the duties of water commissioners has been brought to our attention.

COMMENTS ON POWERS AND DUTIES OF WATER COMMISSIONERS.

The foregoing compilation of legislative enactments defining the powers and duties of water commissioners makes it plain that the office is one of great responsibility and importance, requiring for the efficient discharge of its duties, to carry out both the letter and the spirit of the statute, constant attention, strict impartiality, energy, tact, hard work, and ability. From the very nature of the duties imposed, the fluctuations in supply of water during an irrigating season, the need of its use frequently being greater than the supply, considerable discretion must be exercised by the official in charge. It may be said at the outset that it is probably not possible, with the necessary limitations of human wisdom, for any water commissioner to attain perfection in performing these duties. But every faithful official should aim to attain as near an approach as possible to a perfect discharge of all the duties imposed upon him.

It is to be hoped that in the course of time, and with increased experience, the service will be improved; that mistakes and neglect of commissioners in the past and the injuries resulting therefrom, will occasion greater diligence and care, and more freedom from error in the future; that in time, the sooner the better, the selection of these officials will be removed more and more from the scrambles of politicians, so that a trained class of officials to perform these important duties necessary for the proper development of one of the leading industries of the state, will be evolved. In time, the demands of the irrigators of the state will be such that a faithful, conscientious and experienced official will be retained in office irrespective of the fluctuations in political control of the state government.

An effort will now be made to make some suggestions concerning the proper discharge of many of the duties of water commissioners prescribed by the statutes.

The principal duty of a water commissioner is that defined in the first statute whereby the office was created, tersely expressed in Sec. 2384, M. A. S.

> **"To divide the water in the natural stream or streams of his district, among the several ditches taking water from the same, according to the prior rights of each respectively."**

The language following the above in the statute, conferring power to shut down and fasten the headgate of any ditch not entitled to water is a mere incident to the language quoted.

The duty now under consideration involves consideration of the decrees whereby priorities have been judicially determined. Those decrees fix relative priorities of the several ditches in the stream in whose behalf evidence was introduced, the dates of such priorities, and the maximum amount of water under each priority to which the several ditches were then entitled. They do not provide that the maximum amount so defined under each priority shall be permitted to run into the ditch named at all times, irrespective of the necessities of consumers under the ditch. In most of the districts, perhaps in all, the decree defining priorities was made subject to several conditions, among which perhaps the most important was that which in substance stated that the decree should not be construed as adjudging to any claimant the right to take and carry by means of any ditch or reservoir, any water except to be applied to the use for which the appropriation was made, nor to allow any excessive use or waste of water whatever, nor to allow any diversion of water except for lawful and beneficial uses.

It is not the intention of the statute or of the decrees that the water commissioner, who is the executive officer to see that the decree and its provisions are enforced and observed, shall be permitted to ignore the limitations and conditions stated in the decree, and to deliver the maximum amount constantly throughout the irrigating season to a senior appropriator, or to deliver the maximum amount at any time when it is not actually needed for the necessary and beneficial irrigation of crops. In considering this general power and duty it is necessary also to discuss later statutes enacted for the purpose of emphasizing the importance of certain duties incident to the general power, and necessary to render the same effective. First among such provisions is the fifth section of the act of 1889 making it the duty of the water commissioner to devote his entire time to the discharge of his duties when necessary, and specially to be actively employed on the line of the stream to supervise the water delivery; to keep the same clear of unnecessary dams and obstructions, and to act as a guard of the stream. This requirement

of the statute demands the most constant vigilance. Many grave wrongs have been permitted on account of the failure of water commissioners to discharge this important duty. The writer's attention was called within the last two or three years to the fact that on one of the streams of the state for several years persons having ditches of quite late construction and without judicial decrees, had been taking water from sloughs and tributaries of the river, to the injury of early decreed appropriators on the stream, without any interference or action of the water commissioner to prevent such abuse.

It is manifestly the intention of the law that the water commissioner should act as faithful servant of all the appropriators on the stream, to see that their rights are protected under the judicial decrees. The administration of the water system of the state was provided by the legislature so that there should be some one person to act as agent for all, to see that their rights were respected, so as to obviate the necessity of farmers, busy with their agricultural work, employing a man to patrol the stream and to discover whether or not they were defrauded of their property rights. It is to be feared that there are too many water commissioners who are neglectful of the emphatic language of the statute requiring them to be constantly watchful. Too many commissioners wait to have complaint made to them of unlawful diversions, without themselves taking the initiative in such matters. It is evidently not the purpose of the statute that a water commissioner shall draw a fairly liberal per diem merely for giving orders concerning a few of the main ditches in his district, and waiting for some one to complain that a wrongful diversion is being made by a late ditch from some slough or tributary, or from the main stream itself, but that he should be actively concerned and have his assistants under his immediate supervision active to watch for abuses, and to prevent them, if necessary by the full force of the county.

It would seem that the statute mentioned was passed in 1889 to enforce greater vigilance on the part of the water commissioners. Three sections (Secs. 2386, 2388 and 2391, M. A. S.) were enacted for this purpose. The vesting a water commissioner with the power of a constable, and imposing upon him the duty of prosecuting for violation of his orders, and particularly the fifth section (2391 M. A. S.), making it his duty to be actively employed, supervising and directing putting in headgates, waste gates, etc., and acting as a guard of the public stream, and especially making it a misdemeanor subject to $50 fine to willfully neglect this duty, indicates the legislature was led to believe that the previous general definition of his duty to divide the water according to the prior rights of all, was not found in practice sufficiently definite to bring forth the activity

needed. Everybody knows that the imposing of a penalty to follow a successful prosecution for neglect of duty, is not of itself very effective in many matters, because of the reluctance of citizens to institute such prosecutions, and of the difficulty of obtaining convictions. But the passage of such a statute should have great influence on faithful officials in calling their attention to what is expected of them under their oaths of office. It is sometimes unfortunately true that persons in public service are less disposed to make active and constant exertion than are those in the employ of private persons or companies. It is respectfully urged that the water commissioners of this state should each and all resolve not to fall into such careless habits, but to remember what is expected and demanded of them by the plain language of the law and by their official oaths.

Another duty specially imposed by statute in 1895, which is really only ancillary to the duty of apportioning the waters of the stream according to the prior rights of all, is that defined in Sec. 2384a, Mills' Supplement. The water commissioner is required, on application of the owners of any one or more ditches in his district, at once, thoroughly to examine the ditches under his supervision to ascertain what use of water is being made by consumers. Then if he ascertains the water under any ditch is being wasted, or is wastefully, or extravagantly or wrongfully used to the injury of other appropriators, he must shut off the water supply of such ditch to such extent as in his judgment the water was so wasted or otherwise wastefully or wrongfully used. As the greater includes the less, it is believed that if a ditch owner asks a water commissioner to make an investigation of some particular ditch and not of all of the ditches in his district, he should do so either in person or by a deputy. It will be noted that the third section of the same act of 1895 (Sec. 2384b, Mills' Supp.) makes it a misdemeanor for any water commissioner to fail to perform this duty. It may be further observed that it is certainly not improper, and in many instances it may be the duty of a conscientious official if his attention is in any way called, without formal complaint of a ditch owner, to the fact that water is being wrongfully and wastefully used under some particular ditch in his district, to make the investigation on his own initiative and prevent the abuse if he find it is taking place. It is further suggested that in any event when a water commissioner has reason to believe that any ditch with an early priority is demanding more water at a particular time than it really needs, or for the purpose of using some water for an improper purpose to the injury of some junior appropriator, he can keep fully within the law by advising the superintendent of irrigation of his belief that investigation of such ditch is necessary,

whereupon that official can give him special instruction to make the investigation.

While the power and duty now being considered is specially enjoined by statute and should, whenever necessary, be faithfully and fearlessly performed, it cannot be overlooked, that the power is one of a very delicate nature since it reposes very much discretion in the water commissioner, sometimes likely to be abused and even with the greatest care liable to result in litigation. Each water commissioner should endeavor practically to accomplish the end desired by adopting such a course, at least in the first instance, as will prevent the waste or extravagance complained of or suspected, through the pressure of persuasion and advice before resorting to more arbitrary and extreme measures. To illustrate: If a water commissioner has good reason to believe under some ditch in his district having a large early priority, when water is demanded up to the maximum amount called for by a decree, that with such delivery of water, a good deal is wasted, that the roads under such ditch are flooded, and other like indications of wasteful use are brought to his attention, it may be the part of wisdom for him, first to approach the superintendent or owner of such a ditch, and inform him of his reason to believe that the ditch should get along with considerable less water without anybody being injured, call his attention to the power and duty thrown upon the water commissioner under the statute, and request the superintendent or ditch owner for a few days to see how he can get along with a more limited supply. It is believed in many cases extravagant use of water, particularly that due to carelessness can be prevented, and the rights of junior appropriators in this way be protected without the water commissioner being compelled to go to considerable expense to adopt more rigid and arbitrary methods. However, in all cases when the commissioner finds it necessary, he should vigorously use all the powers given him by the statute to prevent such wasteful use of water.

Under the general power of distributing water with due regard to the prior rights of all, another general topic should be treated. So far as it is possible so to do, it should be the aim of the water commissioner to use the influence of his office to bring about the largest possible production of crops under all the ditches in his district. When he finds that crops are becoming parched and withered under some ditch he can properly seek to persuade owners of ditches having senior appropriations, who are not in very urgent need of water at the time, to make some concessions for the benefit of those in greater need.

In this connection, attention is again called to the early legislation of Colorado Territory, whereby commissioners appointed by the County Judge were required to apportion water

of the stream on alternate days to different localities as they may in their judgment think best for the interests of all parties concerned, and with due regard to the legal rights of all. Experience has shown in distributing water under the larger ditches with numerous consumers, at a time when the supply is limited, much better results are accomplished by delivering the entire available supply alternately, to a fraction of the consumers for one or two days, to other consumers, and so on, because with a better head of water better results can be obtained in a short time than with a small head in a much longer time. The same principle if permitted by law could probably be applied successfully in distributing water among different ditches when the supply in the stream becomes limited. It is, of course, a subject of grave doubt as to whether a water commissioner can alternate the supply in the manner suggested against the consent of the ditch owners affected thereby. But it is suggested, that such consent may be obtained in some instances through the exercise of tactful suggestions by the water commissioner upon the understanding that some benefit will result to the party making the concession, by means of a return concession in his favor later on.

To illustrate: We will suppose that there are two ditches each having a capacity of carrying 100 cubic feet per second, and that there are no other ditches to interfere with the arrangement; that ditch A has priority numbers 1 and 3 each for 50 cubic feet per second; that ditch B has priorities numbers 2 and 4, each for 50 cubic feet per second, and that the river at the particular time under consideration supplies only 100 cubic feet per second for the two ditches, we will say for a period of two weeks. It is evident under the circumstances stated that a strict compliance with the prior rights of the two ditches will give each of them 50 cubic feet per second during the time mentioned. Consumers under both ditches under those circumstances would derive benefit by authorizing the water commissioner to deliver 100 cubic feet per second to ditch A for half the time, and 100 cubic feet to ditch B for the remaining half of the time or on alternate days. It will be noticed that under this hypothetical case each ditch will get just as much water as under the other plan, but the probabilities are that the same amount of water will do very much more good if given in double the quantities for half the time.

The last section of the statute of 1899 confirming temporary loans or exchanges of water, was evidently adopted to apply to just such a case where two ditch companies themselves get together to make such an agreement and notify the water commissioner thereof. But it is here suggested that a water commissioner would be enabled in many instances to accomplish a great deal of good by himself taking the initiative and urging

the owners of different ditches to enter into such an arrangement at times of scarcity. He is familiar with conditions in the whole district, and can see what ditches can be best helped by such an arrangement with justice to all.

Human nature is such that men can be induced to do things by good tact and by persuasion of an official in charge, to which they will not submit under arbitrary exercise of power. It is perhaps unnecessary to state, to enable a water commissioner to accomplish the best results in the exercise of discretion and the use of persuasion, he must have the confidence of the ditch owners of his district as an official who is wholly disinterested and impartial, who is not seeking to aid any particular ditch to the disadvantage of another, but who is conscientiously striving to attain the best result for all the ditches in his district. To attain this confidence, he should have no favorites or pets, he should always show his readiness to respect the rights of senior appropriators; he should be vigilant in protecting the stream and all its sloughs and tributaries from invasions of persons who are wrongfully taking water therefrom. When owners of ditches with early appropriations have full confidence in a water commissioner, when they know that he has supplied them and is ever ready to supply when they really need it with all the water to which they are entitled, they will be much more ready at times when they are not in such urgent need to forego some of their claimed rights at his suggestion for the benefit of others whose crops are suffering. Under such circumstances the senior appropriators will readily acquiesce in suggestions made by water commissioners, believing that they will obtain a full equivalent for any concession they may temporarily make.

Another power or duty required of water commissioners worthy of some comment, is that mentioned in the fifth and ninth sections of the act of 1887 (Secs. 2451, 2455, M. A. S.) The last named sections call for reports to be made by the water commissioners to the superintendent of irrigation as often as required by him. It is to be observed that these reports are to contain not only the special matters mentioned in the statute, but also further information when called for or suggested by the superintendent of irrigation. A water commissioner has more direct and immediate knowledge of the conditions in his own district than does the superintendent of irrigation. Without abusing his power and in full compliance with the spirit of the statute, it is proper and desirable that water commissioners shall make frequent reports, and as the result of their experience make frequent suggestions to the superintendent of irrigation so that that official can study the whole problem in his whole division and make suggestions to other water commissioners helpful to bring about the best results of husbandry.

SUPERINTENDENTS OF IRRIGATION.

POWERS AND DUTIES UNDER THE STATUTES.

As we have already seen, the division of the irrigated area of the state into water districts, each managed by a water commissioner, had its inception in the legislation of the year 1879. The creation of larger divisions, known as water divisions, was made in the year 1881 under an act to provide for the appointment of a state engineer, etc. Four water divisions were created in 1881, and two more in 1889. One was created by proclamation of the Governor in 1901. There are therefore now seven water divisions.

The office of superintendent of irrigation having general supervision over each division was not established until the act of April 4, 1887. The first section of that act (Sec. 2447, M. A. S.) provides for the appointment of superintendents of irrigation for each water division, with proviso that the Governor shall not appoint such official for any division until the Board of County Commissioners of some county included therein shall have adopted a resolution requesting such appointment.

The duties of superintendent are defined in the act. The second section (Sec. 2448, M. A. S.) was as follows:

"Said superintendent of irrigation shall have general control over the water commissioners of the several districts within his division. He shall, under the general supervision of the state engineer, execute the laws of the state relative to the distribution of water in accordance with the rights of priority of appropriation, as established by judicial decrees, and perform such other functions as may be assigned to him by the state engineer."

The third section (Sec. 2449, M. A. S.) provides that the superintendent of irrigation shall be governed by the statutes, and to better discharge his duties he is authorized to make other regulations to secure equal and fair distribution of water in his division in accordance with the rights of priority of appropriation, which regulations adopted by the superintendent shall be merely supplemental to and in aid of the general statutory provisions.

The fourth section (Sec. 2450, M. A. S.) gives the right of appeal to the state engineer from any order or regulation from the superintendent of irrigation.

The fifth section (2451, M. A. S.) requires the superintendent of irrigation to commence the discharge of his duties when the first water commissioner in his district is called out, and to continue to perform the same until the last commissioner therein ceases to be needed. It also provides for reports from water commissioners to the superintendent as heretofore noted.

The seventh section (Sec. 2453, M. A. S.) requires each

superintendent of irrigation within thirty days after his appointment, to send to the Clerk of the District Court in all counties in his division having jurisdiction over the adjudication of priorities, a notification of his appointment, and requesting a certified copy of every decree of the District Court establishing priorities of appropriations of water used for irrigation purposes. It is made the duty of such clerk to transmit such certified copy to the superintendents of irrigation, and that official is then required to cause to be prepared a register of priorities of appropriation of water for his division, based upon such decrees. He is then required to prepare a list of all the ditches, canals and reservoirs within his division, arranging the same in consecutive order according to the dates of appropriations in the whole division, and without regard to their number in each water district alone. He is also required to make a tabulated statement of all ditches, canals and reservoirs in his division, to whom such priorities have been decreed, containing in separate columns,

(a) The name of the ditch, canal or reservoir.
(b) Its number in the division.
(c) The district in which it is situated.
(d) Its number in its proper district.
(e) The number of cubic feet per second to which it is entitled under each priority.
(f) Such other and further information as he may deem useful.

The 8th section (Sec. 2454, M. A. S.) gives the superintendent of irrigation power to call out any water commissioner in his division at any time he may deem it necessary; also power to perform the regular duties of the water commissioner in all districts in his division.

The 9th section of the act of 1887 (Sec. 2455, M. A. S.) provides that all water commissioners in the division shall report to the superintendent of irrigation. The contents of said report have heretofore been referred to in discussing the powers and duties of water commissioners. In addition to the matters detailed in the statute, the superintendent of irrigation is authorized to call for such other and further information as he may suggest. Said official is required to file such reports, to ascertain how water is being distributed, and if as the result of the division into districts, ditches are deprived of water to which they are entitled in the division as a whole by some junior ditch in one district receiving water when a senior ditch in another district which can be supplied with the same water is not receiving its proper supply, then it is the duty of the superintendent to at once order the post-dated ditch, canal or reservoir to be deprived of supply so that the water will run down to the older ditch in the other district. This section specially enjoins upon the superintendent of irrigation to make orders to enforce the priorities of appropriation according to his tabulated statement of

priorities for the whole division, without reference to the district lines. The reports of water commissioners to the superintendent are required to be filed in the office of the state engineer.

In the 10th section (Sec. 2456, M. A. S.) it is provided that when the owner of any ditch, canal or reservoir in any district within the division fails to receive the regular supply of water to which he is entitled, its owner or manager may report the same to the water commissioner, and that official, if he finds it necessary, shall report by wire to the superintendent of irrigation, and said last named official shall thereupon, if he finds he can give such ditch, canal or reservoir a supply at the expense of a latter priority in another district, to enter orders accordingly.

In 1901 there was passed an act in relation to irrigation, found in Session Laws of 1901, pages 193 to 196.

Under the 1st section (p. 193), when the owner of any irrigation structure taking water from any stream fails to erect or maintain in good repair a suitable and proper headgate and measuring flumes or weirs at its point of intake, together with necessary embankments therefor so as to control the water at all ordinary stages, the superintendent of irrigation (or the state engineer), after giving ten days' written notice, is required to refuse to deliver to the owner of such irrigation structure any water until such owner shall erect or repair the headgate and measuring flumes.

The 2nd section (p. 194) pertains to the maintenance of measuring flumes or weirs to determine the amount and volume of water turned into one stream from another, or from a reservoir or ditch into a public stream to be again rediverted. When the owners of a ditch or reservoir so used fail and neglect to erect suitable and proper measuring flumes or weirs for the purpose mentioned, it is made the duty of the superintendent of irrigation (or the state engineer), after five days' written notice, to refuse to allow any water to be taken out from a public stream in exchange for water so turned into the same until the owner shall cause to be erected or repaired such flumes or weirs, both at the point of delivery to the stream and at the point of delivery of taking from the stream.

The 3rd section of the act (p. 194) requires the superintendent of irrigation (or the state engineer) to rate the measuring flume and weir referred to in first and second sections, and to supply the water commissioner of the district where such measuring flumes or weirs are located with a rating table to be used in measuring water.

The 5th section (p. 195) provides that all headgates and measuring weirs used in connection with any irrigation structure to measure and deliver water therefrom and thereto, shall

at all times be under the supervision and control of the irrigation officers of the state.

The 6th section (pp. 195-6) pertains principally to the duty of the owner of a reservoir situated upon or in the bed of any natural stream, to cause a survey to be made of the reservoir with contour lines for every vertical foot in depth, to be properly rated by the state engineer. In case of the owner failing to do what is required, the superintendent of irrigation (or the state engineer) is directed to refuse to permit the use of such reservoir.

COMMENTS ON THE POWERS AND DUTIES OF SUPERINTENDENTS OF IRRIGATION.

Evidently this office was created to relieve the state engineer of duties which otherwise might have been too onerous. It was deemed proper by the legislative department of the government to have a special officer in general charge of all the water commissioners in a single division. The duties of a superintendent of irrigation plainly arrange themselves into two classes. First, the duty to protect senior priorities irrespective of district limits; second, to exercise general supervisory control over all water commissioners in their ordinary discharge of duties. We will discuss these two powers separately.

1st. The power to enforce senior priorities from a main stream as against junior priorities from a tributary of such stream in a different water district, is absolutely necessary to carry out the doctrine of priority of appropriation, since the water of a main stream is practically the result of accretions from its tributaries. Before the enactment of the statute of 1887, there was no proper machinery through the regular water officials to enforce this requirement of the law. Even after the enactment of the statute, little was done until the matter received consideration by the Supreme Court in 1896. It is true that prior to that time, in the case of Strickler vs. Colorado Springs, 16 Colo. 61, reported in 1891, the Supreme Court had declared that any different doctrine would wipe out the principle of priorities upon which our whole system is based. As said by Judge Hayt in that case, "To say now that an appropriator from the main stream is subject to subsequent appropriation from its tributaries would be the overthrow of the entire doctrine."

Still it was not until the decision of the Supreme Court in the case of The Farmers Independent Ditch Company vs. The Agricultural Ditch Company, 22 Colo. 513, handed down May 18, 1896, that the legislation of 1887 had judicial construction. In that case the court, by Chief Justice Hayt, used the following language:

"The legislature, by the act of 1887, has attempted to solve the difficulty by providing an officer and making it his duty to distribute water according to the decrees rendered, without reference to the water district in which such decrees are to be found. As we have said, the act does not attempt to make such decrees conclusive as between the various districts, but, in effect, it provides that until the courts shall determine otherwise in some appropriate proceeding, the superintendent shall treat the decrees as prima facie correct and distribute water accordingly. We believe this regulation is fairly within the police power of the state, as defined in the case of White v. The High Line C. & R. Co., supra, and that it violates no constitutional provision; the effect being only to require the distribution of water in a certain way until such time as the rights of the parties can be definitely ascertained and adjudicated."

Again, in the case of The Lower Latham Ditch Company vs. The Louden Irrigation Canal Company, decided March 5, 1900, reported in 60 Pac. Rep. 629, it was held that the plaintiff having priorities in water district No. 2 from the South Platte river was entitled to a decree requiring the water officials to protect its priority, if necessary, at the expense of junior priorities, from the Big Thompson river, in water district No. 4.

In view of the rule of priority in time giving the better right, the statutes and the judicial decisions, it must now be regarded as beyond controversy that one of the principal duties of the superintendent of irrigation is, without fear or favor, to issue such orders as will enforce senior rights in one district, when they cannot otherwise be supplied, by cutting down the supply of junior rights in other districts on tributary streams.

In connection with this duty of a superintendent of irrigation some discretion must be exercised in determining to what particular water commissioner orders shall be directed, where there are many tributaries supplying the same main stream, having in view the location of the particular ditch needing relief, and the location of junior ditches from which its needs may be supplied. The prime duty of the superintendent is to furnish water to the senior appropriator in the main stream needing it. It may be that such senior appropriator is needing water at a time when thirty different juniors are enjoying water under several tributaries of the main stream and in several districts. In theory, the latest appropriation should be the first cut down, but if, in fact, that appropriator is forty or fifty miles away, and another junior is within a few miles, relief can best be given by depriving the junior on the nearest tributary. In practice, the latter course usually will be found to be necessary. The superintendent in such cases may be able to supply the needs of the senior appropriator by reducing to some extent a large number of juniors, thereby interfering less violently with the regular distribution of any particular district.

Another matter worthy of special note in this connection which must be considered by the superintendent of irrigation.

grows out of natural conditions. The writer was informed that on one occasion older ditches in the vicinity of the town of Sterling, in Logan County, were needing water when junior ditches in Morgan County were fairly well supplied, and that a large amount of water, by order of the superintendent of irrigation, was shut out of the junior ditches and required to run into the South Platte river in the month of July or August, when the heat was very great and there was very little water in the main stream, and it was found that all, or nearly all of the water thus taken from the junior ditches was lost by evaporation and otherwise in the sand beds of the South Platte river. In that particular instance, as reported, it was found practically impossible to supply the senior ditch. In 1901 another test was made in the same locality, resulting in large increase of supply, it is claimed, to ditches near Sterling. It is here suggested that in all such cases the superintendent of irrigation should not hastily jump to conclusions, but should in perfect good faith endeavor to supply the senior appropriator, and not refrain from so doing until convinced that natural conditions render it practically impossible.

2nd. The remaining class of duties devolving on a superintendent of irrigation pertain to his general control over the water commissioners in his division, his duty to execute the laws pertaining to distribution and in so doing to make rules and regulations, to carry on correspondence with all his water commissioners, and, at times, if necessary, actively to discharge the duties of a water commissioner. All suggestions made concerning the duties of water commissioners apply equally to superintendents of irrigation. If the superintendent keeps up a constant and active correspondence with all commissioners in his division and makes frequent suggestions to them concerning the proper discharge of their duties, he can be a great aid in reducing the whole work of his division to a more perfect system. By such correspondence he can learn how thoroughly each commissioner is discharging his duties; if complaints are made to him of inefficiency of service in some district, he can give the water commissioner thereof the benefit of his knowledge as to the more efficient conduct of some other water commissioner in another district. If suggestions by correspondence fail to remedy negligence or inefficient discharge of duty in some particular water district, he can, if he sees fit, himself perform the duties of water commissioner in that district for a short time, and thus by personal example give the water commissioner full knowledge of what is expected of him. The power conferred on superintendents of irrigation to obtain information from water commissioners on any subject pertaining to irrigation in his division as he may suggest, enables a brainy superintendent who desires to use the entire power of his office to improve and perfect the

system, to do much in that direction, to become a center from which radiates an energy and an influence which will make himself a potent factor in the perfection of the system, whereby the purpose and intent of the law will be carried out, and the best interests of the state and its agriculture be subserved.

Water commissioners and superintendents of irrigation, in carrying out the orders of the state engineer, and in aiding that official in the discharge of his duties, also will improve the efficiency of the system as a whole.

Incidental to all the other duties of a superintendent of irrigation there should not pass unnoticed his importance as a peacemaker and settler of petty disputes, which may arise in his division and the several districts thereof. Much unnecessary litigation doubtless has been and hereafter will be prevented by superintendents of irrigation on the line here suggested. A visit of that official to a water district in which a commissioner is having serious trouble and disputes with ditch owners has a wholesome influence leading to amicable adjustment of such controversies.

It has sometimes been believed that the office of the superintendent of irrigation was somewhat superfluous. Persons inclined to that view have taken the position that the state engineer, as the general center of authority and supervision of all water districts, would be sufficient. Development of agriculture and irrigation is such, however, and the other duties of the state engineer necessarily take so much of his time and attention that it would be difficult, if not practically impossible for any state engineer, however capable, fully to discharge the duties of all the superintendents of irrigation without being compelled to neglect other important duties of his office.

It is believed by the writer hereof that if the superintendents of irrigation constantly devote themselves to a study of the water distribution in their respective divisions and to the thorough and efficient discharge of all of the duties of their offices, both advisory, administrative, appellate, and corresponding, they can constantly be employed and become important factors in improving the water service of the state.

THE STATE ENGINEER.

POWERS AND DUTIES WITH REFERENCE TO IRRIGATION MATTERS.

In 1881 an act was passed providing for the appointment of a state engineer in Colorado and of his assistants, and for the establishment of water divisions. (Sess. Laws 1881, pp. 119 to 122). The first five sections of the act cover the matter of water divisions, and the remaining seven sections had reference to the office of state engineer or "state hydraulic engineer," and his duties. The last seven sections were repealed upon the en-

actment of a new statute on the subject in the year 1889. The original act (Sec. 6) gave the state engineer supervision over the water commissioners of the different water districts in the state. In section seven the state engineer was required to make careful measurements and calculations of the maximum and minimum flow of water in each natural stream from which irrigation ditches took their supply; also to collect facts and make report as to the system of storage reservoirs, and to keep full records of his work, observations and calculations. The tenth section required the state engineer to prepare and render yearly, and oftener if required, full reports to the Governor. The eleventh section required the state engineer, on request of any interested party, on payment of his expenses, to measure and ascertain the capacity of any ditch, canal or reservoir thereafter constructed or enlarged, and to give an official certificate concerning the same. The twelfth section provided that the owners of any ditch, canal or reservoir having decreed water priorities should construct and maintain, under supervision of the state engineer, measuring weirs to measure in cubic feet per second water at the headgate of such ditch, canal or reservoir, or as near thereto as practicable, and the state engineer was required to arrange in tabular form a computation showing the amount of water that would pass such weir in cubic feet per second at different stages or height of water therein, and to furnish copy thereof to the water commissioner interested.

The act approved March 30, 1889, pertaining to state engineer, repealed the last seven sections of the act of 1881, and in lieu thereof adopted eleven new sections still in force. This change removed all the qualifications formerly required. In the original act "no person shall be appointed as such hydraulic engineer who is not known to have such theoretical knowledge and practical skill and experience as shall fit him for the position."

The 1st section (Sec. 2458, M. A. S.) concerned the appointment and qualifications of the state engineer and other like matters.

The 2nd section (Sec. 2459, M. A. S.) gives the state engineer general specific control over the public waters of the state; requires him to make careful measurements of the flow of the public streams of the state from which water is diverted and to compute the discharge; also to collect data and information pertaining to the location, size, cost and capacity of dams and reservoirs to be constructed, similar data concerning the feasibility and construction of reservoirs on eligible sites on which he may obtain information; also data and information regarding the snowfall in the mountains each season to predict the probable flow of the water in the streams.

The 3rd section (Sec. 2460, M. A. S.) requires the state

engineer to approve plans and designs for construction and right of way of all dams or reservoir embankments in the state exceeding ten feet in vertical height.

The 4th section (Sec. 2461, M. A. S.) gives the state engineer general charge over the work of water superintendents and water commissioners, requires him to furnish them with all data and information necessary for the intelligent discharge of their official duties. It also requires the superintendents of irrigation and water commissioners to report to the state engineer at suitable times, and especially to make annual statements on blanks furnished by him of the amount of water diverted from public streams under their control and other statistics which he deems of benefit to the state.

The 5th section (Sec. 2462, M. A. S.) pertains to the duty of the state engineer, on the request of any party interested, on payment of his expenses, to appoint a deputy to compute and measure any canal, dam or reservoir or any construction of like nature.

The 7th section provides for the appointment of deputies by the state engineer, under his control, and for whose official actions he shall be responsible.

The 9th section (Sec. 2466, M. A. S.) enables the state engineer to request the owners of any ditch having decreed priorities to construct and maintain under his supervision measuring weirs at or near the head of such ditch, canal or reservoir. The state engineer is required to compute and arrange in tabular form any statement concerning the amount of water that will flow through such a weir at different stages, and furnish a copy thereof to any superintendent or commissioner having control.

The 10th section (Sec. 2467, M. A. S.) makes a cubic foot per second a unit of measurement of flowing water, and a cubic foot the unit of measurement of volume.

The 11th section (Sec. 2468, M. A. S.) requires the state engineer to prepare a full report of his work bi-ennially and to deliver the same to the Governor to be laid before the general assembly.

We have already noted that the fourth section of the act of April 4, 1887 (Sec. 2450, M. A. S.) gives the right of appeal to the state engineer from any order or regulation made by any superintendent of irrigation.

In 1897 an act was passed to provide for and to regulate the exchange of water between reservoirs and ditches and the public streams. (Sess. Laws of 1897, pp. 176-7.)

The 1st section requires the state engineer to determine what reasonable deduction shall be made for seepage and evaporation when a person or company shall divert water from one

public stream into another and then divert it from the latter stream.

The 2nd section requires any person or company so transferring water from one public stream to another to construct and maintain, under the direction of the state engineer, measuring flumes or weirs and self-registering devices where the water leaves its natural watershed and is turned into another, and also where it is diverted for use from the public stream.

In the 3rd section it is made the duty of the water commissioner of the district where the water is used, to keep a record of the water so turned into his district.

The 4th section permits, without injury to others, the owner of a reservoir to deliver storage water either into a ditch or into a public stream to supply early appropriations, and in exchange therefor to take from the public stream higher up an equal amount of water, with deduction for loss, if any, to be determined by the state engineer. The same section requires the person or company desiring such exchange to construct and maintain, under the direction of the state engineer, measuring flumes or weirs and self-registering devices at the point where the water is turned into the stream or ditch, so that the water commissioner may readily determine and secure a just and equitable exchange.

In 1899, an Act in Relation to Irrigation, adopted, had special reference to the matter of changing the point of diversion by an appropriator when it can be made without injury to the prior rights of others, and a judicial consideration in advance of the proposed change. In connection with the procedure, the state engineer is to receive and file a copy of the map and decree permitting the exchange, and thereupon to issue a notice to the water commissioner in charge, notifying him of the change. (Sess. Laws of 1899, p. 236, Sec. 2.)

Also in the year 1899 an act was passed in relation to reservoirs. (Sess. Laws of 1899, pp. 314 to 317.)

The 1st section provides that no reservoir of a capacity of more than 75,000,000 cubic feet, or having a dam or embankment in excess of ten feet in vertical height, and covering more than twenty acres shall thereafter be constructed, unless plans and specifications therefor shall first be approved by the state engineer. The state engineer is required to act as consulting engineer during the construction of such reservoir, with authority to require the work to be done to his satisfaction. A written statement concerning the work of construction and the completion thereof to his satisfaction must be given by the state engineer specifying the dimensions and capacity of the reservoir.

The 2nd section provides for the expenses of the state

engineer, and a per diem for his services to be paid by the reservoir owner.

The 3rd section requires the state engineer annually to determine the amount of water which it is safe to impound in the several reservoirs within the state. It is made unlawful for the owner of any reservoir to store therein water in excess of the amount determined by the state enginer to be safe.

The 4th section makes it the duty of the water commissioner to withdraw from any reservoir any water impounded therein in excess of the amount determined by the state engineer to be safe, and to prevent the reservoir to be refilled beyond the limit fixed.

The 5th section makes it the duty of the state engineer, when complaint is made to him by persons so located as to be in danger if the embankment of a reservoir should break, that the reservoir is in an unsafe condition, or being filled so as to render it unsafe, to make an examination of the reservoir and determine the amount of water which can be safely impounded therein. If on such examination he finds the reservoir unsafe, or being filled so as to render it unsafe, he shall cause water to be drawn off to such an extent as to render the same safe and prevent further storage of water beyond what he considers the safety limit.

The section enables the state engineer to use any force necessary to perform the duties previously mentioned. It is also made the duty of a water commissioner in such case, if an attempt should be made to refill the reservoir, to act as provided in the fourth section.

The 7th section provides for compensation to the state engineer for mileage and other expenses incurred in making examination.

The 8th section provides for an appeal to the court from any decision of the state engineer in such matters, but with the proviso that the decision of the state engineer shall control until the case is finally disposed of in the courts.

The 9th section provides for owners of reservoirs being responsible for all damages in case of breakage.

The 10th section provides that any reservoir company which after ten days' written notice has been given, fails to obey the directions of the state engineer with reference to the construction or filling of any reservoir, shall be subject to a fine of fifty dollars for each offense, and each day's continuance after the time of notice has expired shall be considered as a separate offense.

In addition to the duties required of the state engineer on the general subject of irrigation, distribution of water, etc., above referred to, many statutes have been passed requiring that of-

ficial be a member of divers boards of control of sundry internal improvements, to perform important services about state canals, with reference to desert land entries, and many other similar matters not pertinent to this paper except as showing how much of the time of the state engineer is necessarily invaded by other duties besides the important ones above indicated.

An act in relation to irrigation, passed in 1901, has been referred to at the close of the statement of powers and duties of superintendents of irrigation. All the powers conferred upon superintendents of irrigation by that act are also conferred upon state engineers. The sixth section of said act of 1901 (pp. 195-6) makes it especially the duty of the state engineer, on the request of the owner of a reservoir situated upon or in the bed of a natural stream, at the expense of the owners thereof, to cause a complete survey of the contour lines of said reservoir to be made for each vertical foot in depth, and also when he deems it necessary of fractions of a foot; also to prepare a table showing the number of cubic feet capacity of said reservoir for each foot in depth and fractions thereof, and to place a gauge rod in said reservoir, marked in correspondence with the contour lines. In event the owner fails to cause said survey, etc., to be made, it is made the duty of the state engineer to refuse to permit the reservoir to be used until such survey, etc., is made.

COMMENTS ON POWERS AND DUTIES OF THE STATE ENGINEER.

The mere recapitulation of the functions of the state engineer as the head of the system of irrigation and distribution of the state, his supervisory control of all water commissioners and superintendents of irrigation, his appellate jurisdiction over subordinate officials, his special duties with reference to the measurement of canals and reservoirs, his supervision and control over the construction of reservoirs, his duty to provide for self-registering devices in many instances, is sufficient of itself to make plain the responsibility of his office.

It is plainly within the intent and purpose of the statute that the state engineer must devote considerable time to a thorough study of the whole system of irrigation distribution of the state. In that connection he must become familiar with the work of the several superintendents of irrigation, and satisfy himself that they are properly performing the duties by law of them required. This also applies to the reports of the several water commissioners. As the state engineer is required to be a man of professional ability as an irrigation engineer, his advice and suggestions to superintendents of irrigation and water commissioners should be of special helpfulness. The result of his study

should enable him in his reports to make suggestions to the Governor, and thereby indirectly to the legislature on any desirable change in the law from time to time. His office has always been, and ever should be, of special importance in perfecting the efficiency of the official water service of the state.

The state engineer should insist on obedience to the statute law by persons constructing reservoirs, and by those who desire to exchange water between reservoirs and public streams, or to turn water from one public stream into another. Since the water commissioners are under the control of the state engineer, it is believed that it is within his power to direct water commissioners to refuse to recognize the rights of persons to divert water which is turned into a public stream from some other source of supply, unless the statute concerning self-registering devices and other legal requirements are complied with. The purpose of the statute is that exact justice may be done. The person who adds to the amount of water in a running stream by turning water therein from another stream or from a reservoir, should certainly be entitled to again draw the same amount of water from the stream as a just reward for his enterprise and capital invested. But on the other hand, every safeguard against abuse of this privilege, and to prevent the diversion to the injury of regular appropriators from the stream of a greater amount of water than is supplied thereto, after proper allowance is made for incidental losses, should be rigidly enforced.

Special comment should be made with reference to the importance of measuring weirs at the headgates or canals. It is unfortunately true and well known that when many of the decrees concerning priorities were rendered by the courts, sufficient care was not taken to have correct measurements made, whereby any ditches were decreed priorities really in excess of their carrying capacity. When for a large number of years it has been shown by experience, and as the result of careful measurement, that a ditch has not carried and cannot carry the amount provided in the decrees, sufficient data will be collected to prevent the subsequent enlargement of such ditch to enable it for the first time to carry the maximum mentioned in the decree, and thereby injuriously to affect the rights of junior appropriators. Moreover, such measuring weirs are of great value and aid to the water commissioners in distributing and apportioning the water at times of scarcity, and when ditches having several priorities limited to one or more of their earlier ones.

Bulletin 68. March, 1902.

The Agricultural Experiment Station

OF THE

Colorado Agricultural College.

ARKANSAS VALLEY SUBSTATION.

PASTURE GRASSES.
LEGUMINOUS CROPS.
CANTALOUPE BLIGHT.

By H. H. GRIFFIN.

PUBLISHED BY THE EXPERIMENT STATION
Fort Collins, Colorado.
1902.

THE AGRICULTURAL EXPERIMENT STATION,

FORT COLLINS, COLORADO.

PASTURE GRASSES FOR THE ARKANSAS VALLEY.

BY H. H. GRIFFIN.

For years there has been considerable inquiry in regard to pasture grasses for this valley. The farmer is often heard to remark "I wish I could get something on which to pasture a cow, this alfalfa is so dangerous."

Almost since the establishment of the substation pasture grasses have been tested for their adaptability to this section, but one of which has been reported upon in bulletin form, viz: Bromus inermis in Bulletin 61.

The behavior of other grasses has been reported from time to time in the annual reports but this information is not generally accessible to the public.

Enough data has now been obtained in regard to the adaptability of all of the most important grasses, to warrant publication.

The theory of permanent pastures is a very fine one. Farmers are more and more giving up the idea on lands under irrigation. I believe the farmer can get more feed and much greater returns from the land in a regular rotation of crops. One acre of alfalfa cut and properly fed will keep an animal the year round. With pastures, much more land must be devoted to one animal.

It will not pay the small farmer to devote much land to pasture. There are others having larger farms who do not look so closely to the return per acre, who do desire some grass for stock pasture. Often there are waste lands or tree claims that can be devoted to pasture.

The first work in testing grasses was done in 1891. Mr. Huntley, then superintendent, reports on these in the annual report of the Experiment Station for 1894 as follows:

"Based upon trials of three years' duration, but two grasses out of eight tried, have given promise of enduring field culture for pasture. They are Bromus and Orchard grass. The unsuccessful ones were, Hard Fescue, Meadow Fescue, Perennial Rye grass, Italian Rye grass, Red Top and Blue grass. It is quite probable some of these would succeed in moist soils of other localities in the state."

The report for 1895 mentions only the Bromus and Orchard grass as making good showing that season.

The varieties tested in addition to those above mentioned since the writer took charge in 1898 are, the Tall Oat grass and Meadow Fescue (*Festuca elatior*) sometimes called English Blue grass.

Bromus inermis has been quite extensively reported upon in Bulletin 61 and the reader is referred to it for information. It may be said that the results in 1901 confirm the report made of it in bulletin 61.

Orchard grass, Tall Meadow Fescue, Tall Oat grass and Blue grass comprise the list of grasses that may be profitably grown here for pasture.

ORCHARD GRASS. (*Dactylis glomerata.*)

This grass is uniformly successful in the Arkansas valley, whether sown on the dry uplands, in timber claims or in moister lands. It is a tall grass growing in clumps but is valuable for either pasture or hay. It may be sown profitably with alfalfa. It matures with the first crop and would improve the quality of the hay for feeding horses.

This grass is easily started and does not need nursing to get it established; it resists drouth and hot weather well. It is one of the first things to appear in the spring. When pastured off, it soon starts growing again.

Owing to its nature to grow in tussocks, it is advisable to sow some other grass with it to occupy the intervening spaces. Either the Tall Oat grass or the Tall Fescue is adapted to the purpose, preferably the latter.

Orchard grass, like many others here, does not fail to grow some during the hot weather. It also stands irrigation well, not becoming sod bound.

About 25 pounds of seed per acre should be sown.

TALL MEADOW FESCUE. (*Festuca elatior.*)

This grass is sometimes called English Blue grass. In ordering the seed of this grass it must not be confounded with another grass called Meadow Fescue (*F. pratensis*) in the catalogues.

The latter kind has never been successful at the station.

Tall Fescue has not been under trial so long as the Orchard grass but its value has been fully demonstrated to the uplands of this section. It forms a thick vegetation and is so persistent as to gradually thicken up; the seed shoot growing about two feet in height.

Reports from the Kansas Experiment Station speak well of it.

It is a valuable grass in the Arkansas Valley; alone, or in combination with others.

Sow about 25 pounds of seed per acre.

TALL OAT GRASS. (*Avena elatior.*)

This grass is largely grown in the southern states where it is highly valued.

It does well in this valley but does better if sown in mixture with Orchard grass. It has been difficult to get a good stand of this grass owing to the poor germinating power of the seed.

This grass will remain partially green nearly all winter and will commence growth very early in spring.

All reports of this grass with which I am familiar give it very high nutritive qualities. At least two bushels of seed should be sown per acre.

KENTUCKY BLUE GRASS. (*Poa pratensis.*)

Climate has much to do with pasture grasses. It is a well known fact that Blue grass cannot stand hard use and long continued dry hot weather. It is said "whoever has limestone land has Blue grass," and while we have plenty of lime in the soils of this section, yet Blue grass cannot be relied upon for pasture, owing to the vast amount of irrigation it requires to keep it thrifty. Nearly everyone is aware how much irrigation this grass requires when it is grown for lawn, which is sufficient demonstration that under but few conditions can it be relied upon for pasture.

Lands having considerable clay or adobe with an abundant water supply will produce this grass in sufficient quantity to make good pasture. But put under conditions where it must withstand drouth it will perish at a time when Orchard grass or Tall Fescue would be in good condition.

In most instances it will require considerable nursing to secure a stand and it is only when ornament and utility are both desired that it is advisable to grow Blue grass for pasture.

RED TOP. (*Agrostis vulgaris.*)

This grass has not been a success on the dry upland soils of the station.

I see no reason why this grass should not succeed upon some of the moist low lands and sub-irrigated lands of this valley. The writer has seen this grass succeed in other localities under similar climatic and soil conditions to those above mentioned.

TIMOTHY. (*Phleum pratense.*)

Timothy is not a success on the uplands and it can hardly be said to be on any lands in the valley.

I do not believe the returns will warrant sowing it at all.

WHEN TO SOW GRASS SEED.

There are two times of year only when grass seed may be sown with good success in this country, viz: March and August.

By sowing in the former month, the grass gets a start before the weeds come on to choke it out and besides it will sometimes get the benefit of April storms.

In many respects August is the preferable time to sow. There are no weeds or foreign grass to choke the young grass. The weather becomes cooler and damper and the young plant receives the benefit of summer rains that usually occur.

The plant gets well established before winter and starts the next spring strong and vigorous to take possession of the land.

If sown in August, the farmer may take a grain crop from the land previous to sowing, but if the grass is sown in the spring the season is lost for anything but the grass.

FALL SEEDING OF ALFALFA.

Sometimes conditions of crops and labor are such that the farmer wishes to sow alfalfa in the fall. He wishes to know if it may be done with impunity.

In the first week of September 1898 the station sowed three acres to alfalfa. This was just preceeding the severe winter of 1898-99 in which the thermometer registered $-32°$. A good rain came soon after the seed was sown and the seed came up nicely, the plants getting about two inches high when winter set in. A few spots died out during the winter but the greater part of it stood the extreme cold weather well.

The weather conditions that winter were the worst ever recorded in this country and the results seem to indicate that alfalfa may be sown in August or early September with impunity.

The rules given for the sowing of grass seed hold good in regard to the sowing of alfalfa seed.

LEGUMINOUS CROPS FOR THE ARKANSAS VALLEY.

BY H. H. GRIFFIN.

For three seasons the sub-station has been testing leguminous plants to ascertain what may be expected of them in this valley. The main object has been fertility, but incidentally their value for forage, for bees and mulch or cover crops for the soil.

The plants under investigation are the Serradella, Red Clover, Cow pea, Field pea, Soy bean and Hairy vetch.

SERRADELLA. (*Ornithopus sativus.*)

The Station failed to secure a single plant of this legume. The writer has seen other trials in the arid region with this plant but has never seen them successful. The plant does not seem to be adapted to arid conditions.

RED CLOVER. (*Trifolium pratense.*)

This legume does not thrive under our arid conditions. However, in old orchards where there is partial shade, or in open fields where the soil is rather heavy and water supply abundant, some success may be secured with Red Clover.

To be of much value as a fertilizing plant it must occupy the land for at least three years and as there is not much revenue from it in the interim, it becomes an expensive plant to grow for field fertilizing.

The only place for which we can recommend it at all is old orchards and it is doubtful whether it is advisable to use there, as there are other plants better adapted to our conditions.

COW PEA. (*Vigna catjang.*)

This is a valuable plant for the Arkansas Valley. The Station has tested the Whipporwill, Black, Clay and New Era varieties. The former we consider the most desirable owing to its upright growth. This variety will ripen if sown as late as the last of May.

As high as two tons of hay per acre have been cut on land devoted to this plant, besides leaving a considerable

quantity of vegetation to be incorporated with the soil. The roots are well supplied with tubercles. It will produce from 6 to 10 bushels of seed per acre, which is relished by poultry or hogs, and about two tons of hay.

The New Era variety will mature seed in about one month less time than the Whipporwill and may meet a demand for late sowing in orchards. It does not grow nearly so rank as the Whipporwill.

This plant should be sown in drills from 22 to 32 inches apart. The work may be done by a grain or beet drill. One or two early cultivations should be given, after which it will cover the ground. This plant can be sown as late as the first of July where intended only for fertilizing purposes. It is a splendid plant to sow in orchards to relieve the trees from the reflection of the sun in late summer, winter and early spring, after which it may be plowed under as a fertilizer.

Two plats, one-tenth acre each, that produced Cow peas in 1900, were devoted to the growth of beets in 1901. The peas were cut with a mower so that only the roots and stubble remained to plow under. Two plats of the same size that had never been fertilized, and which had grown crops similar to those on which the Cow peas were sown, were planted to beets also for comparison. Both plats were given the same treatment. The plats on which the Cow peas had been grown yielded 16 tons per acre, the other plats yielded 12.5 tons per acre. That the nitrogen supply was augmented by the growth of the peas was apparent from the color and vigor of the beet tops.

THE FIELD PEA. (*Pisum arvense.*)

The Field pea does fairly well at Rocky Ford if sown very early in spring, so that its growth may be made before the approach of hot weather.

The seed should be sown the latter part of March. The peas will ripen the first week in July.

The yield on the Station grounds in 1901 was 23 bushels from two acres. The yield in 1899 was at the rate of 16 bushels of seed per acre. In addition to the yield of grain there was produced at least 3 tons of splendid feed on the two acres. The above returns are only medium, for in neither case were the conditions such as to give the best returns

The variety grown in 1899 was the "Mummy;' that grown in 1901 was the "Marrowfat." I consider either of them preferable to the Canada pea for this section.

This pea may be sown with oats early in the spring; the product cut for hay late in June and the ground devoted to some other nitrogen gathering crop for the remainder of the season.

From 100 to 120 pounds of seed should be used per acre. I think the most desirable way to cover the seed is to plow it under.

THE SOY BEAN. (*Glycine hispida.*)

The Soy bean is an upright, bushy, leafy plant growing about 3 feet high and requiring about 100 days to mature.

The station has grown the Early Yellow and the Medium Early Green.

The bean of this plant is extremely rich in protein and is especially desirable for combining with corn or sugar beets for pork production. When utilized this way no threshing is required.

The Kansas Experiment station has made some extensive experiments with Soy beans in combination with other foods (especially Kaffir-corn) for feeding pigs. The results are reported in Bulletin 95, and show a gain of 96 per cent. by the substitution of one-fifth Soy bean meal to a Kaffir-corn ration.

This plant resists drouth well; the Kansas station claims it is fully equal to Kaffir-corn or sorghum in this respect.

The Soy bean may profitably be grown under many ditches with scant water supply, in place of corn, especially if the soil is rather light and needs improving in fertility.

The seed should be sown with a grain or beet drill about the middle of May, putting the rows from 22 to 32 inches apart. About 40 pounds of seed per acre is required. The yield ranges from 10 to 25 bushels per acre. The harvesting should be done before the pods begin to turn yellow or great loss will ensue from the popping open of the pods. But one crop can be grown in one season on land devoted to this bean, owing to the time required to mature it.

Land devoted to Soy beans in 1900 and planted to sugar beets in 1901, gave as high as 6 tons greater yield than adjacent land having no fertilizer applied.

HAIRY VETCH. (*Vicia villosa.*)

Hairy Vetch is known as Sand, Winter, or Russian Vetch.

Some of the farmers of the Arkansas Valley have expressed their desire for a plant that may be sown in the fall, after taking a crop from the land, and make sufficient growth to turn under in the spring, thus adding fertility to the soil.

Hairy Vetch meets this demand admirably. It will make growth in this valley during all but the severest part of the winter. It makes its poorest showing during the heat of summer. For this reason it is preferable to sow in late summer or fall.

The station has secured good results from sowing as late as October first.

In one instance the seed lay in the soil over winter and germinated with the first approach of spring; the plants produced seed in July, but of course the results are not so good as where the plants become well established before winter.

The Hairy Vetch will thrive on the lightest kind of sandy soils and where sown in the fall, will keep such lands from blowing during the spring months, afterwards adding a vast amount of humus and fertility to them. The roots are bountifully supplied with tubercles. If this plant is sown in early September it will produce a considerable growth to plow under in April or May, or if allowed to ripen will do so in early July. It will bloom, about the middle of May and from that time on until it ripens is a vast profusion of bloom. Bees frequent it in great numbers, seeming to do so to the exclusion of most other plants. Early fall sowing makes splendid pasture during April and May, and if the plant is started in the summer it will furnish pasture in February or March.

Six-sevenths of an acre was sown to this seed, August 11, 1899. By May 12, 1900, it stood two feet high and commenced to bloom. The seed was ripe the first week in July, at which time it was cut.

The yield of straw was 3000 pounds, which yielded 400 pounds of seed. July 26, the same land was prepared by a disc harrow and watered, and from the seed that scattered off, a good stand of the vetch was secured, which was allowed to grow until April 1901, when it was plowed under and the land seeded to beets.

Two acres near by were given a dressing of ten loads of sheep manure per acre and one acre was left without manure as a check.

The tops of the beets on the vetch land grew rank and thrifty, having the dark healthy green and much of the appearance of beets on alfalfa land.

The results show a heavier yield than was obtained from the use of manure and as much as 50 per cent, increase over the land not fertilized.

Trials in 1901 show further, that the vetch may be sown with oats and be cut with them for hay in July, after which it will produce seed.

This plant may be sown in orchards late in summer and make a splendid cover crop to overcome reflection from the snow in winter and early spring, after which it may be plowed under, adding much fertility to the soil.

The plant is easily destroyed and in no sense will become a nuisance.

It is already apparent that the farmers of the Arkansas Valley must fertilize and rotate crops if success is to be obtained. The larger farms are being more and more cut up into smaller ones.

On small farms alfalfa cannot be grown to advantage; it takes too long to get it established and after it is well established, it is difficult to eradicate.

The small farmer should get the best possible results from his farm, and if leguminous crops can be so combined that he may take two crops from the same land in one year, they will be of profit to him.

The following outline will briefly show how some of the crops above mentioned may be combined as fertilizers: Field peas may be sown early in spring with oats and cut for hay the latter part of June. The ground may then be planted to Mexican beans.

Field peas may be sown early and allowed to ripen seed, after which the land may be devoted to Cow-peas which may be either turned under or cut for hay.

Hairy Vetch may be sown in the fall and plowed under in the following spring. Mexican beans or Cow-peas may follow it.

Cow-peas may be sown quite early in the spring and cut for hay, after which the land may be sown to vetch and the growth turned under the following spring.

By some such system of cropping as outlined above, the farmer can make his supply of yard manure do much greater service.

The above mentioned crops will enter nicely into a 3 or 4 year rotation with cantaloupes, beets or tomatoes.

CANTALOUPE BLIGHT IN 1901.

BY H. H GRIFFIN.

Bulletin No. 62, gave full information of our results looking to the control of the cantaloupe blight, closing with the season of 1900.

The work in 1901 was planned as follows: To treat the seed with Bordeaux mixture to control the blight; to determine at what stage of growth the spraying should be done to be most efficient

The work attempted on the station grounds was destroyed by a hailstorm the 24th day of July. Some knowledge was gained of the efficacy of early spraying in a field belonging to a Mr. Dixon. He had sprayed one part of his field twice and another part three times. The first spraying was done when the vines had started to run slightly. The second spraying was done about the time the melons were setting on the vines, the third about the time picking for market commenced.

At the time I saw the field (first of September) there was a marked difference in the vines in the two lots. Those sprayed early (hence had the three sprayings) were in much the better condition, and Mr. Dixon said the melons were of better quality. Mr. Dixon has used the Bordeaux spray for two seasons and is very enthusiastic over the benefits to be derived from its use for control of cantaloupe blight.

Another field that was given one spraying late in July, was thrifty and bearing splendid melons (August 26) when fields across the fence had been abandoned for ten days, both fields having produced melons the previous year.

The sprayed field was also near two fields of melons growing on alfalfa sod that about September first were apparently in the best of condition. By Sept. 18th, the fields on the alfalfa sod were almost destroyed by the blight, while the sprayed field remained in quite good condition and was yielding melons of good quality. The sprayed field of 14 acres, yielded 3300 crates of marketable melons Mr. Crum, the owner, after two years' trial of the spray, is well pleased with the results.

After the destruction of the vines on the station grounds a part of an adjoining field was sprayed. This had been

heavily manured with sheep manure and was planted the last of May. The work was done July 30th, at which time the vines were almost covering the ground.

About the 25th of August, the blight was making rapid progress in all melon fields. The benefit derived from the spraying in this field was especially well marked. About Sept. 1, the unsprayed vines were giving up fully twice as many melons per day as the sprayed vines. The latter were ripening somewhat as they would under normal conditions, but the others, both vine and fruit, were deteriorating rapidly.

A portion of a field on the station that was planted the first of June, and which recuperated after the hail, was given two sprayings, one late in September and again about ten days after. The results confirm the results given elsewhere in regard to the efficacy of the Bordeaux for the control of the blight.

That nothing but fresh lime should be used in the preparation of the Bordeaux was especially emphasized in this work. We used some air slaked lime, as it happened to be at hand, and a portion of the vines were badly injured by the spray, giving them much the appearance of a bad case of blight. There was one significant feature of this, the vines that were apparently badly injured by the spray recuperated and looked well afterwards, while those attacked by blight grew worse.

There is evidence that the blight is more than a local trouble. The writer happened to visit some melon fields in the vicinity of Brighton, about September first, and there saw the blight doing serious injury. Reports and specimens of melon leaves sent me from Grand Junction indicate that the disease is well established there. The observations of this year verify those of last year in that the disease is well distributed over the entire Arkansas valley. Both the farmers and the shipping agents realize that the trouble is a serious one and are considering its consequences. That the trouble was only temporary is no longer held as a tenable opinion, but rather one demanding such treatment as will lessen its ravages.

The weather conditions have been the most favorable for a study of the disease of any I have ever had in that it was more of a typical season. Two of the former seasons were extremely wet during July and August and that of 1900 was very dry. The rain of the last season was moderate in amount and well distributed. Two features were prominently brought out this year. One was to avoid the use of any heating manure previous to planting melons and the

other was the necessity for rotation of other crops with cantaloupes. A comparison of cantaloupe fields in close proximity, some of which were on alfalfa sod, some on grain land and others on cantaloupe ground, revealed the great benefits to be derived from the use of the alfalfa land. Land that had been in melons for a number of years showed the blight in about the same ratio as the number of years to which the land had been cropped to melons. Heating sheep manure is especially undesirable to precede melons.

I had under observation, this year, one field in which the seed had been planted March 28. April 18 the seed was practically in the same condition as when planted. April 27 the seed was irrigated; many of the seed sprouted but no plants up. May 8 some of the plants were up and had the third leaf, others were just coming up, while about one-third of the field had to be replanted. The first ripe melon was taken July 27.

Comparing this field with others the conclusion can be aptly drawn that had the planting been done one month later the results would have been fully as good, if not better Last Spring was one of the most favorable of springs for extremely early planting.

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PLANT DISEASES

OF 1901.

—BY—

WENDELL PADDOCK.

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PLATE I.

Apple trees killed by too much water and root rot.

PLANT DISEASES

OF 1901.

By WENDELL PADDOCK.

INTRODUCTION.

A brief account is given in the following pages of some of the plant diseases which have come to our attention during the past season. Only a few of these were brought to our notice by correspondents, and it is the purpose of this bulletin to stimulate a greater interest in the subject, for it is reasonable to suppose that these pests of our crops will increase in Colorado as they have done in older States. By prompt attention many of them may be overcome or controlled. In a State so large as ours it is impossible for one or two men, with the time at our disposal, to visit very many different localities. It is, therefore, desirable in the interest of all that any untoward condition of crops, be it due either to insects or fungi, should be reported to the Experiment Station. Specimens of the affected plants should in all cases accompany the report.

Now a word as to the nature of plant diseases. This term is commonly applied to a class of plants known as fungi, and sometimes to the result of unfavorable soil or atmospheric conditions, but rarely to insect attacks. The following pages have to do mostly with fungi. These plants are low in the scale of development and are mostly of microscopic size, though some of them, as toad stools and puff balls, are familiar objects. Plants of this class are unable to take nourishment from the soil, consequently they must live on food that has been prepared by other plants. Many of them live on decaying vegetable matter, but others are true parasites, attacking live plants and thus becoming of economic importance. These tiny plants have organs that correspond to the roots, branches and seeds of higher plants.

The seed-like organs or spores, go through a process of germination much the same as a grain of corn. Being so small they are readily borne about by the wind and when they chance to fall on the kind of plant to which the fungus is adapted—its host plant—and the conditions are favorable for germination, the fungus readily gains a foothold.

It has been found that spores are unable to germinate in the presence of small amounts of copper, and advantage is taken of this fact when plants are sprayed with Bordeaux mixture. The copper in the mixture protects plants, hence the better the spraying is done the more complete is the protection. The fact that Bordeaux is not a cure should be borne in mind, and to be a successful preventive it must be applied before the spores are disseminated.

Fungi that live in the soil and attack the roots of plants are not dependent on spores as a means of dissemination. The root-like organs, or hyphæ, spread through the soil from plant to plant, or they may be distributed by the cultivator or other means. With root diseases the treatment is more complicated, since there is usually no way of telling that a plant is affected until it is past recovery. A systematic rotation of crops is often of help in keeping annual and biennial plants healthy, but with orchards little can be done after the trees are attacked. Good care in every respect will be a great aid in keeping the trees free from disease.

Many of the fungi which produce disease in plants are invisible to the unaided eye, hence they are apt to be regarded as something mysterious and the effects are often ascribed to other causes. The action of climate, altitude, winter injury, alkali and water are often mistaken for the effects of attacks of fungi. For example, the potato failures in the vicinity of Fort Collins have long been thought to be due entirely to peculiar conditions of soil and climate, notwithstanding the fact that the famous Greeley potato district lies only twenty miles east and in the same altitude. Experiments conducted at this station during the past year prove that the lack of success is due primarily to root diseases which thrive much better in our heavy soil than in the lighter and better drained soils in the potato district. The fact that we have occasional successes here is no doubt largely due to planting clean seed in soil that is free from disease, or the conditions are not suitable for the best development of the fungi during certain seasons.

APPLE TREE ROOT ROT.

The presence of an unusual amount of yellow foliage on fruit trees last spring attracted attention in various localities in Northern Colorado. It is a well known fact that too much water will produce yellow foliage, and this is the cause that is commonly thought to be accountable for this condition. As the leaves usually regain their normal color before the close of the season but little attention is given to the subject. An unusual amount of rain in the early summer was probably the cause of this general appearance of yellow foliage, but many fruit growers have noticed that occasional trees are affected in this manner year after year and finally die without any apparent cause, while adjacent trees remain healthy. It is not

PLATE II.

Winter injury of apple trees induced by peculiar soil conditions.

PLATE III.

Blackberry roots injured by Rhizoctonia. Natural size.

uncommon for such trees to die in the latter part of summer, when the fruit and foliage wither and cling to the dead branches. Such trees are usually comparatively loose in the soil, in fact, some of them may be tipped over while they are yet alive. Upon examination the larger roots will be found to be in an advanced stage of decay, and the feeding roots finally become so reduced that there are not enough left to support the tree.

Certain fungi are constantly associated with the diseased roots, and it is probable that they are ultimately responsible for the death of the tree. As a result of numerous examinations, it was found that these same fungi also attack the roots of trees that are apparently healthy. Now it is easy to conceive that these diseases may live on the roots of a tree for a number of years without doing much harm, but as soon as the tree is weakened from any cause the fungus makes rapid advance.

Trees that take on yellow foliage from overirrigation suffer a temporary check in growth, from which they apparently recover in a short time. But if this is repeated year after year the ultimate effect must be very injurious. A wet, heavy soil, however, produces ideal conditions for the growth of root destroying fungi which appear to be abundant in our State, and when a favorable opportunity occurs they become destructive.

Winter injuries, which result in sun scald, black heart, freezing of the roots and dry freezing of both roots and branches, are potent causes of the weakening of the vitality of trees in some sections of the State. Trees may be injured in some one of the above ways and yet not show any marked indication that anything is wrong.

A good deal of damage is also done to fruit trees by the attacks of wooly aphis, which are abundant in many localities. They increase rapidly if left undisturbed, and the greater portion of the root system may soon be infested. These conditions result in serious injury and trees may even be ruined by such attacks. Root fungi are not slow to take advantage of the enfeebled roots, and it is likely that in many instances they rapidly extend these injuries.

In some localities the natural drainage of the soil is poor, and it is evident that too much water is being used in irrigating. In a number of orchards visited the level of the water in the soil had been raised till the lower roots of the trees were apparently surrounded by a saturated soil most of the time. This is particularly true of small orchards, where the owners grow small fruits or truck crops between the rows to supplement the income from the orchard. Root fungi thrive remarkably well under these conditions, and the combination of causes is doing no small amount of damage. One orchard came under my observation where all of the trees on an area of about two acres had been ruined. (See Plate I.). Another orchardist reports a yearly loss of about 25 out of an orchard of 1,000 trees. Instances of this kind might easily be multiplied.

That the trees are injured by water under these circumstances cannot be doubted, since no agricultural plant can thrive in a saturated soil. We have not yet demonstrated the exact relation which fungi bear to this condition, but it is evident that they play an important part in the destruction of the trees. Certain species are usually found on the roots of diseased trees and attacking healthy tissue. Moreover, young trees have been known to be killed in one season, apparently by root rot, when planted in the places from which dead trees had been removed.

This subject is a most perplexing and important one, and one that is as yet but little understood. We expect, however, to make it one of the principal lines of investigation of this Section for the coming season. In the meantime certain sanitary measures may be mentioned that might well be observed by many orchardists.

When it becomes evident that too much water is being used in irrigating, as is indicated by yellow foliage, or by the raising of the level of the water in the soil, more use might well be made of the cultivator. By keeping the surface of the soil loose much of the water is prevented from evaporating, thus lessening the necessity of frequent irrigation. The trees should be kept in a thrifty condition, and yet not allowed to make a rapid growth, which produces soft tissues that easily succumb to attacks of blight. On some soils it may be best to keep the orchard seeded to alfalfa, but usually better results will follow a systematic use of cover crops. The many advantages to be derived from the use of cover crops cannot be discussed here, but with this system of cultivation some crop is sown in the orchard in late summer or early fall which is plowed under the next spring. Mr. Griffin has found that the best leguminous plant for this purpose at Rockyford is hairy vetch. (See Bulletin No. 68 of this Station). Since this plant is one of the nitrogen gatherers it may not be advisable to use it on all soils; in such cases winter rye may be used instead. In localities where the attacks of blight are severe, it may be advisable not to plow the crop under till late in the spring and thus avoid a rapid early growth of new wood.

APPLE TREE ROSETTE.

A peculiar condition of apple trees was brought to our attention on Rogers Mesa in Delta county by the Horticultural Inspector. More or less of the trouble occurs in a number of orchards in this locality, consequently it is a matter of considerable interest in the county. Some of the trees are dying, while there are a number of dead limbs on others, but the characteristic feature of the disease is a tuft or rosette of small leaves at the end of branches that are otherwise nearly bare of foliage. (See Plate II.). The similarity of this condition to the peach tree rosette, a common disease in portions of

the Southeast, was so great that the presence of a new apple tree disease was suspected.

I visited this section in July and collected numerous specimens, but no parasitic organism could be detected by laboratory investigation. Later on Mr. C. H. Potter visited some of these orchards and made valuable observations on the soil formation. I visited the locality again in September in company with Dr. Headden, and as a result of our observations and study, together with the experience of the fruit growers, we arrived at the following conclusions:

Much of the soil on the Mesa contains an excess of marl and in many places this substance forms a solid substratum. At the edge of one orchard visited the owner was digging and burning it to make a cement to be used in mason work. The marl in itself is, perhaps, not harmful to plants; in fact, when judiciously applied to land it acts as a liberator of plant food, but when present in excess the soil is infertile. This is shown by the fact that when roots penetrate the marl substratum they send out few or no fibrous roots. The roots do not usually penetrate this substratum to any extent, consequently the trees are often shallow-rooted in orchards where the layer of marl is close to the surface. The level of the lowest roots on one dying tree was only ten inches below the surface of the soil. At this depth they branched out horizontally, where they were readily injured by lack of moisture and by the action of frost. But a more immediate cause for this condition of the trees is found in the water supply. Water is plentiful during the early part of the season, but in the latter part of June the supply has usually been exhausted. The nature of the soil is such that it readily dries out and the trees suffer for moisture, consequently growth stops and the tissues harden. In the latter part of July a partial supply of water is again turned into the ditches and the orchards are irrigated. The result is that in many instances these trees make a distinct second growth which is immature when cold weather comes on. Those branches which are not killed outright but are severely injured during the winter put forth a feeble growth the following spring. The end bud, usually being the strongest, lives at the expense of the others, consequently many of the side buds soon die if they start into growth at all, and the terminal one develops a contracted branch on which the leaves are crowded, thus forming the rosette.

Second growth is not always necessary, however, for the appearance of this disease. Shallow-rooted trees planted in a soil that is quickly dried out are easily injured during the winter. This probably accounts for the fact that the disease first attracted general attention after the hard winter of 1898-99.

One orchard was visited in which a small number of diseased branches had appeared, but which had been promptly removed or severely cut back early in the spring. At this date, October 5, the

trees appeared to be perfectly healthy and had made a vigorous growth which showed no sign of disease. This experiment tends to confirm the conclusion that the difficulty is due to local conditions and not to a specific organism which might spread to other portions of the valley.

Apparently the same difficulty is figured and described in a recent *California bulletin in which the author ascribes the cause to the presence of alkalies in the soil. He states that apple trees are injured "by 1,200 pounds of carbonate and 3,000 pounds of common salt per acre distributed through four feet depth."

The particular soil on Rogers Mesa that was examined contained 1,820 pounds of common salt per acre taken to a depth of one foot. While this is a much larger amount of salt than the trees are said to be able to endure in California, most of the trees do not show any sign of the affection, though they have been planted nine years. This statement is confined to the first foot of soil, because it is doubtful if there is any portion of the orchard where the soil is four feet deep. Moreover, the subsoil is a marl into which the trees had thrown very few roots.

The amount of sodic carbonate in this soil was not determined. However, we have had occasion to observe a nursery that was established in a soil in which the sodic carbonate content was determined and found to be 2,800 pounds per acre, taken to a depth of four feet. The trees made an excellent growth for three years and showed no sign of the rosette affection.

While these observations do not prove that this condition of apple trees may not be produced by the action of alkalies, they point to the conclusion that such an effect is improbable under our conditions.

Treatment.—Apple trees should not be planted on soil where the marl substratum comes close to the surface, as it will result in shallow-rooted trees with its attendant evils. In other portions of the district an attempt should be made to make the soil deeper and to add to it substance and fiber. Many Colorado soils are deficient in vegetable matter, consequently they become compact and dry out rapidly. Depth may be gained by plowing deeply before the orchard is planted, and vegetable matter added by turning under strawy stable manure or green manure. For the latter purpose some form of clover, vetch or rye may be used, preferably in the form of a cover crop, which should be sown in the latter part of summer and plowed under during the following spring. If water for fall irrigating is available the crop will make growth sufficient to afford considerable protection to the roots against the action of frost and from drying out by winter winds. Finally, by a judicious use of water, of which

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*Laughridge, R. H. "Tolerance of Alkali by Various Cultures." Calif. Agri. Expt. Sta. Bull. 133:14.

PLATE IV.

Fig. 1. Cherry tree injured by mound parasite.
Fig. 2. Detail of apple limbs shown in Plate II.

PLATE V.

Fig. 1. Spore pustules of rust fungus on branch of Asparagus. Enlarged.

Fig. 2. Aster killed by Fusarium.

Fig. 3. Raspberry leaves curling at edges. The result of an attack of Rhizoctonia on the roots.

an abundance is promised the Mesa for the coming season, it is not likely that this disease will be very injurious on soils that are of sufficient depth to make suitable orchard land.

APPLE INJURY FROM SPRAYING WITH BORDEAUX MIXTURE.

Complaints were received from correspondents at Canon City and Montrose that spraying with Bordeaux mixture had seriously injured the fruit of certain varieties of apple trees. The injury produced is well shown in the illustration in Plate VIII., Fig. 3, which is from a photograph of a Ben Davis apple that is so disfigured as to be unsalable. This variety appears to be very susceptible to such injury, though a number of other kinds were injured more or less. All degree of disfigurement occurred, from a slight russeting of the skin to the malformation shown in the figure.

That the corrosive action of Bordeaux mixture is responsible for this condition there can be no doubt. The subject has attracted considerable attention in the Eastern States, where it has been found that such injuries are much more common in some seasons than in others. Just what the conditions are that favor this action of the mixture have not been determined and the subject is still in an experimental stage. This is particularly true of the arid regions, since fungicides are just beginning to be used here on fruit trees.

In the light of our present knowledge, it can only be recommended that great care be taken to see that the mixture is properly made. The formula on a subsequent page has been found to be sufficiently strong for combating fruit-tree diseases as they occur in other States. Further experience with spraying in Colorado may show the necessity of modifying the formula to suit our conditions. And, finally, Bordeaux mixture should not be used unless it is needed. In the vicinity of Canon City it is said that the bitter rot of apples is abundant and the orchardists sprayed their trees with the mixture for the purpose of combating this disease. But in the majority of the fruit growing districts apple trees are not yet affected to any extent by such plant diseases as can be controlled with Bordeaux mixture.

BLACKBERRY ROOT DISEASE.

(*Rhizoctonia.* Sp.)

There was a noticeable amount of light green or yellowish foliage on the blackberry and raspberry plants in the College plantation last spring, which did not regain its normal color. Later in the season leaves on occasional plants began to curl and shrivel as though suffering for moisture, and some of the plants died. Appar-

ently healthy plants exhibited this latter symptom. (See Plate V., Fig. 3). Upon examination, the bushes were found to be attacked by a root fungus which is closely related to the one which is so destructive to potatoes. (See Bulletin No. 70 of this Station). All parts of the plant below ground were attacked, but the greatest injury occurred on the canes above the crown. Here, as shown in the illustration in Plate III., the bark was discolored and shrunken from the crown to the surface of the soil, or a short distance above. The fungus grows on and within the bark, destroying the tissues, and thus interfering with the movement of plant food. The injury commonly extends around the cane, and when it becomes deep enough to cut off the supply of moisture and food, the plant dies.

The presence of the yellowish foliage was probably due to a badly diseased root system at the beginning of the season. An excess of moisture in the early part of the season was favorable to the growth of the fungus, which made rapid inroads on the plant's vitality. That they were poorly nourished, was indicated by the yellow appearance of the leaves.

The drying up of leaves on apparently healthy canes may have been due to a vigorous attack of the fungus which, because of favorable conditions, was able to seriously injure the plant in a short time.

This fungus, *Rhizoctonia*, is destructive to a great variety of plants, and it is widely distributed in the State. There are possibly several species of the fungus, which may be destructive to different plants. Little is known about the disease, and some investigators regard it as a sterile fungus, or one that produces no spores. But our investigations indicate that *Rhizoctonia* is but a stage in the development of a fungus of which some species are well known under another name.

There is no way of curing diseased plants, nor a practical means of preventing the disease from spreading after it makes its appearance in a plantation. It is a wise precaution to destroy all affected plants, but even this severe measure will not rid the soil of the fungus. New plants filled in such vacancies are liable to become diseased in a short time. It has not been determined how long the fungus will persist in the soil, but a new plantation should not be set on land where diseased plants have stood for at least four years.

It is undoubtedly the same fungus which attacks both blackberries and raspberries, hence raspberries should not be set on land where diseased blackberries have recently been grown, or *vice versa*.

Finally, when setting a new plantation, great care should be taken to get plants from stock that is known to be free from the disease.

CHERRY TREE WOUND PARASITE.

Mr. Hankins, Horticultural Inspector for Larimer County, called my attention to a disease of cherry trees in an orchard at Berthoud, where about fifty trees in a young orchard of sour cherries had been destroyed. All of the badly diseased trees then remaining were found to be injured on the trunks, similar to those shown in the illustration in Plate IV., Fig. 1. Large areas of bark had been destroyed which were still clinging tenaciously to the wood. The larger wounds were conspicuous, and when the dead bark was removed, as shown in the figure on the left, it was plain that these injuries were the cause of the death of the trees. In some instances, the trees were nearly girdled, but where the injury was of less extent, the loss of the bark, together with the drying out of the exposed wood, had interfered with the nutrition enough to kill the tree. All other parts were in normal condition.

The owner informed me that the orchard had been neglected and the trees bruised by careless hands while it was in charge of a renter. It is likely that such wounds afforded entrance to some fungus which belongs to a class known as wound parasites. These fungi are unable to penetrate living bark, but when they gain access to the tissues through a wound they are able to entend the injury. On examining closely, an abundance of white hypha was found beneath the dead bark, but what part the fungus took in the injury, if any, has not been determined.

Some neglected trees in the vicinity of Fort Collins were found which showed similar symptoms. These trees had been torn by wind and bruised by hail, thus producing wounds through which fungi could enter readily.

The loss of trees in the younger orchard would probably not have occurred if greater pains had been taken in cultivating. When wounds are accidentally or necessarily made they should immediately be protected by a coat of thick paint or grafting wax. By taking such precautions it is not likely that this disease of cherry trees will cause much damage.

ASPARAGUS RUST.

(*Puccinia asparagi*).

A portion of an asparagus plant, as shown in Plate V., Fig. 1, affected with rust, was received in October from a gentleman at Rockyford. This is probably the first time that this fungus has been reported from this State, and while it has done but little damage as yet, its presence here is of importance, as it has done a large amount of injury to asparagus plantations in other States. In some localities, where many acres of asparagus were formerly grown,

the crop has been practically abandoned because of the ravages of this disease.

The fungus has three stages in its development which appear at different times during the season. The form which usually attracts attention first comes on the canes rather late in the season, when numerous dark brown pustules are pushed out through the bark. These pustules are composed of masses of spores, as are also the dark streaks and patches of a still later stage, which also form on the canes.

These last spores remain on the brush or fall to the ground, where they are ready to spread the disease by attacking the new shoots the following season. The fungus lives within the tissues of the plant, and where badly affected the plant is so weakened that but little food is stored for the succeeding crop. This results in a reduced yield, and if the disease is not checked the bed becomes unprofitable and many of the plants are killed.

By way of prevention it has been suggested that the tops of the plants be cut off and burned early in the fall before the spores fall to the ground. This method has the disadvantage, however, of being injurious to the plants, as in order to be effective the tops must be removed before the plants are matured. This process may injure the plants nearly as much as the fungus.

* Sirrine reports flattering results in combating the disease on Long Island by spraying with a resin-Bordeaux mixture. (See formulas). He expresses doubt, however, whether this method will always pay, since the applications must be frequent and very thorough, thus involving considerable expense. In these experiments from three to five sprayings were given, beginning in July after the cutting season was over. In the case of small beds it will no doubt be a better plan to destroy the plants and start anew on uninfested soil.

ASTER WILT.

(*Fusarium.* Sp.)

The asters on the College campus were nearly all destroyed last season by a species of *Fusarium.* (See Plate V., Fig. 2). The plants appeared vigorous and gave promise of abundant bloom up to the time the blossoms were beginning to open, when many of them began to wilt and in a few days were dead. In no instance, so far as noticed, were isolated plants affected; in some beds all of the plants were killed, while in others only those in certain areas died.

On examination the stalks were found to be discolored for a space of one to three or four inches above the surface of the ground.

*N. Y. State Agr. Expt. Sta. Bul. 188.

The light pink spore masses of the fungus were very abundant on this area. It is likely that the disease was in the soil when the plants were set out and that it gained access to the plants through the crown or upper roots, as the root system was also badly diseased.

The fungus grows within the tissues and absorbs the nourishment of the plant. Finally the communication between root and top becomes obstructed by the collapse of cells and the filling up of the passages by the fungus hypha.

The only remedy that can be suggested for this disease, since the fungus lives in the ground, is to replace the soil in the beds with fresh earth. This would be practicable only with small beds. But it is possible that the soil can be freed of the fungus by taking certain sanitary precautions. Such measures would consist, first, in burning all diseased plants as soon as they are detected, thus preventing further dissemination of spores; second, asters should not be grown for two or three years in beds where the disease has appeared; the fungus will probably be starved out during this time.

CURRANT CANE DISEASE.

(*Nectria cinnabarina*).

Currant bushes in the vicinity of Fort Collins are seriously affected by a fungus which attacks the canes. It is especially severe on neglected bushes in back yards, but the College plantation, which has always been given good care, was so badly diseased that it was thought best to destroy it. The fungus was also found in an active condition on gooseberry bushes that stood in adjoining rows.

Yellow foliage and dying canes are characteristics of this disease, which often occur on a bush where a portion of the plant appears healthy. As is common with some other plant diseases, many of the canes die after the fruit becomes of considerable size and both fruit and foliage shrivel and cling to the stems. Badly diseased plants are frequently killed. The reproductive bodies of the fungus occur in great abundance on the dead canes in the form of brick-red masses or tubercles, which are shown natural size in Plate VI., Fig. 2.

*Spraying with fungicides is not likely to prove practical as a preventive of this trouble, as spores may be produced at any time during the season. All that can be done is to remove the entire plant and burn it as soon as any part shows evidence of the disease. If allowed to lie on the ground the affected parts may mature spores and spread the disease to other plants. It has been determined that the fungus lives from year to year within the tissues of the currant plant, and that a plant may be infested for some time without show-

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*Durand, E. J. Cornell Univ. Agri. Expt. Sta. Bul. 125.

ing any evidence of disease. Therefore cuttings should not be taken from a plantation in which this fungus has appeared.

GRAPE ANTHRACNOSE.

(*Sphaceloma ampelinum.* De By.)

During the month of June the grape vines in the College vineyard were found to be seriously diseased with anthracnose as is shown in the illustration in Plate VII. Numerous dark colored pits or depressions occurred on the young canes and on the stems of the leaves and fruit clusters. Many of the spots grew into each other as the disease progressed, thus forming continuous depressions which in some cases nearly girdled the affected parts. The centers of the depressions also took on a whitish color, and finally very minute raised points or pustules appeared, in which the spores are born.

The first effect seen on the leaf blade was in the form of fine, irregular cracks with brown edges. Later in the season the leaves presented a torn and ragged appearance where two or more cracks ran together. Leaves attacked when quite young were severely injured and their surface materially reduced, as shown in the plate.

The characteristic appearance of diseased fruit is well shown in the illustration where one fruit is attacked and a seed exposed through a circular wound. The diseased berries do not decay, but the affected portions become hard and shrivelled.

In Europe, as well as in many portions of the Eastern States, this fungus has proven difficult to combat. When once well established in a vineyard it has usually taken two or three years of most thorough treatment to get it under control. Fortunately, however, the disease does not spread rapidly.

It is recommended that the vines be sprayed thoroughly with Bordeaux mixture, beginning early in the spring at the time when the buds are commencing to swell. This treatment should be followed by four or five others made at intervals of about two weeks.

PEA ROOT DISEASE.

During the season of 1900 Mr. C. H. Potter, assistant in Horticulture, gave considerable attention to a destructive pea disease which made its appearance in the vicinity of Longmont. The trouble was not generally distributed, but was confined to certain fields. In these fields where the disease was most severe a majority of the plants were killed before reaching the surface of the ground. Different fields presented all variations in the amount of injury, from partial to complete failures of the crop.

The disease was not so destructive last season, as only a few

fields showed evidence of its presence. I examined one tract of land that had been sown to peas at the usual time in the spring. Most of the seed failing to grow, the ground was plowed and again sown to peas. At the time of my visit the field had the appearance of fallow land, as only an occasional pea plant was to be seen.

The soil in the vicinity of Longmont is well adapted to pea growing, about 2,500 acres being grown there annually to supply the canning factory, which makes a specialty of this product. The fields in which the disease made its appearance have always produced good crops of other kinds. A good crop of wheat grew the year before on the one that I examined.

My attention was called to this disease first in September of 1900, when I took up the work of this department, but no investigations could be undertaken at that time. During the following winter some soil was secured from an infected field, which was placed in flats in the greenhouse and sown to peas.

The plants grown in this soil were nearly all attacked by fungi on the roots and on the stems below ground. The injury was not severe enough, however, to kill them, and as the vines grew and bent over they were attacked at the point where they came in contact with the earth. These diseased areas were soon overrun by various saprophytic fungi, so it was difficult to tell what was the real cause of the trouble. However, there was a large colored hypha constantly present in the diseased parts and the same hypha was found to be abundant in specimens collected in the field by Mr. Potter the summer before and preserved in formalin.

All attempts to cultivate the fungus artificially failed, since it produced no spores and the diseased areas on the stems were so contaminated with other forms that efforts to secure cultures by other means failed. The distinctive character of the hypha showed that it belonged to a group of fungi commonly known as *Rhizoctonia*, and that it was closely related to if not identical with the disease that is so destructive to potatoes in this State.

The soil was then turned over to Mr. Rolfs to determine whether it was infested with this potato fungus with which he was working. A part of it was placed in pots and planted to potatoes. Eight pots were planted with clean potatoes that had been treated with corrosive sublimate to free them from disease. The soil in another lot of eight pots was sterilized with steam for three days, two hours a day, to kill all plant life that it contained. These pots were planted with clean potatoes treated as above. In the first series all the plants were affected with *Rhizoctonia*. In the second all of the plants, with one exception, were free from the disease. The presence of the fungus in the one pot may easily have been due to carelessness in watering, as it stood by the side of the others that contained the unsterilized soil.

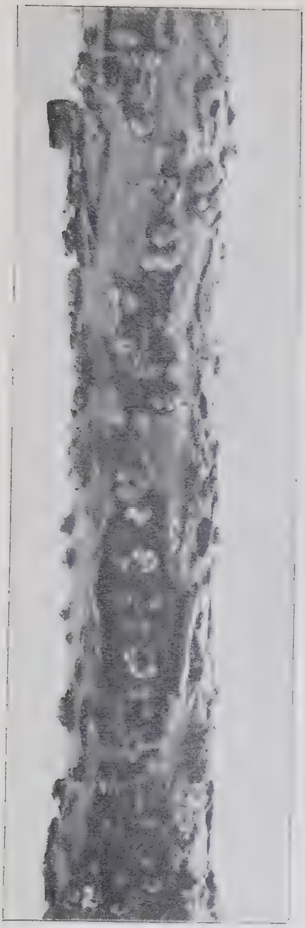
Inoculation experiments were undertaken with potato *Rhizoctonia*, both with pure cultures and with the sclerotia as they occur on potato tubers. Peas were germinated in the laboratory and when the caulicle was about an inch long the inoculation was made. Some of the fungus from the cultures was placed between the caulicle and the cotyledons; then the peas were planted in coarse river sand in the greenhouse. Peas that were not inoculated were planted at the same time to serve as a check on the work. The result of the experiment shows that the fungus occuring on the potato is parasitic on the pea, as the roots of all inoculated plants were badly diseased and in some instances the caulicle of the young plant was cut off. But in no instance were the plants killed, as they threw out new roots above the injury and were able in a measure to overcome the disease. Roots of the pea plants that were injured by the fungus in these inoculation experiments are shown in Plate VI., Fig. 1. The check plants grown under the same conditions, but not inoculated, showed no signs of disease. These experiments were repeated and varied by placing portions of the fungus under both caulicle and plumule. *Rhizoctonia* sclerotia taken from potatoes and started into vigorous growth by placing them in a moist chamber over night were used in the same way; the results were the same as before.

These experiments do not prove conclusively that the so-called *Rhizoctonia* disease of potatoes is the cause of this trouble with peas, but the indications point strongly to this conclusion. It is known that this fungus is destructive to a great variety of plants and these experiments show that it may injure peas. That it did not kill the pea plants in the inoculation experiments may be due to the fact that conditions in the greenhouse were not suitable for the best development of the fungus. The failure of the fungus to kill the peas that were grown in the greenhouse in soil from an infested field must also have been due to unfavorable conditions.

As a result of these observations and experiments it is safe to conclude that the pea disease is due to a fungus that is in the soil when the peas are planted. There is no practical way of detecting its presence until its effects are seen on the pea plants, consequently the discovery of a method of treatment would seem to be a difficult matter; some suggestions, however, obtained from the study of other plant diseases may be of value.

First—The heavier soils should be avoided for pea growing, as root diseases, especially the fungus that attacks potatoes as mentioned above, is much more severe on such soils.

Second—By deep plowing the diseased surface soil may be buried so deeply that the fungus will not come in contact with the young roots. After the pea plants are thoroughly established it is probable that the fungus will have only a slightly injurious effect,



COLORADO
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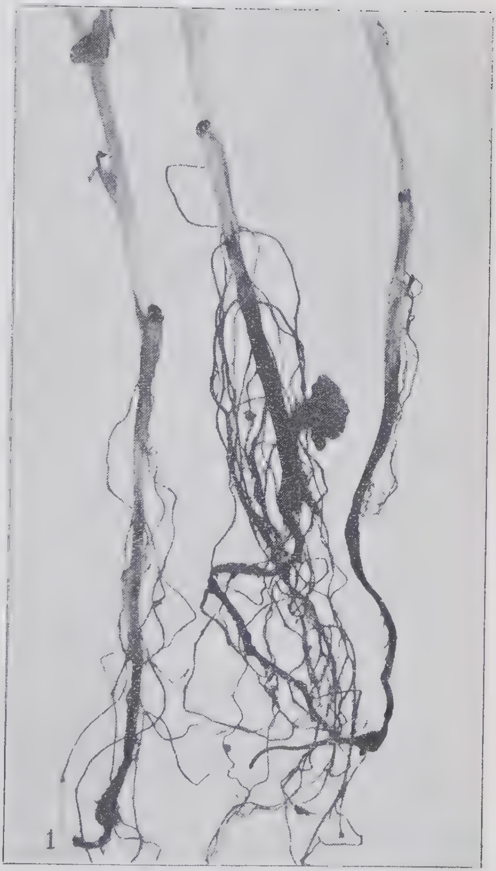

PLATE VI.

Fig. 1. Pea roots injured by inoculating with Rhizoctonia from potato.

Fig. 2. Fruiting bodies of Nectria cinnabarina on currant canes. Both figures natural size.

PLATE VII.

Anthracnose of the grape. Showing injury to cane, leaf, leaf stem, fruit and stem of fruit cluster. Natural size.

as the experiments indicate that the disease is most destructive when the plants are small.

Third—As little water should be used in irrigating as can be gotten along with, since root fungi in general thrive best in a wet soil.

Fourth—It is within the range of possibilities to secure a variety, or strain of some variety, of peas that will resist the attacks of this fungus. Recent reported advances made in plant breeding encourages us to believe that such a strain may be secured, and we hope to undertake work of this nature the coming season.

PLUM LEAF BLIGHT, OR SHOT-HOLE FUNGUS.

A common disease of plum and cherry trees, known as leaf blight or shot-hole fungus, is illustrated in Plate IX., Fig. 1. A common effect of the fungus is to destroy small areas of leaf tissue, which drop out and leave circular holes, thus suggesting the name. When many of these holes run together the greater part of the leaf is destroyed. If the fungus is severe in its attack and the leaf surface is materially reduced during the active growing season great injury is done to the trees.

Numerous experiments have proven that this leaf blight may be easily controlled by spraying with Bordeaux mixture. *Beach recommends that three sprayings be made as follows: The first about ten days after the blossoms have fallen; the second about three weeks after the first, and the third about four weeks after the second.

This disease is reported as being quite abundant in some seasons in sections of Colorado. In such localities it will undoubtedly pay to give the treatment recommended a trial.

POTATO DISEASES.

Potato diseases are being made the subject of special investigation at this Station, as mentioned on another page, and a report of progress of the work is soon to be published in bulletin form. Whether the fungus that has been found to be so destructive to this crop can be entirely overcome has not been determined, but much good can be done by treating seed potatoes.

It is our purpose merely to call attention to the subject at this time, and for the sake of convenience, formulas for disinfecting seed potatoes are given on the following page.

*Beach, S. A. Rep. N. Y. State Exp. Sta. 1896, p. 399.

An extended discussion of this subject will be found in Bulletin No. 70 of this Station.

FORMULAS FOR TREATING DISEASED SEED POTATOES.

Corrosive sublimate	1 ounce
Water	8 gallons

Dissolve the corrosive sublimate in one gallon of hot water, then dilute with seven gallons of cold water. Allow the potatoes to soak one and one-half hours. When dry they may be cut and planted, though it has been found to be a good practice to treat the potatoes a week or more before planting, since the treatment may retard germination if done just before planting.

Corrosive sublimate is a deadly poison, and it should be used in wooden or earthen vessels, since it corrodes metals.

Formalin	8 ounces
Water	15 gallons

Soak the potatoes two hours in this solution, preferably a short time before planting. This remedy is somewhat more expensive than the corrosive sublimate treatment, but it has the advantage of being non-poisonous, and it may be used in any kind of vessels.

QUINCE RUST.

(*Gymnosporangium.* Sp.)

Last season the quinces in some sections of the Western slope were quite generally attacked by a fungus that is commonly known as rust. The fruits were often much distorted and worthless, as shown in the illustration in Plate VIII., Fig. 1. Any part of the fruits may be attacked, but in this case the blossom end was elongated into a hard knotty mass, on the surface of which was many fine tube-like projections about a quarter of an inch long, in which spores were produced. Fruits which were attacked when quite young were much dwarfed and so distorted that they scarcely resembled quince fruits. The fungus may also attack the stems and leaves of quince trees, but on the few trees that were hastily examined, it was only found upon the fruit.

The peculiar and interesting life history of this plant disease was worked out a number of years ago, which is briefly as follows: The fungus has two stages in its development, which are produced on two distinct classes of plants. The first stage occurs on cedar and juniper trees, on which it produces enlargments of the twigs and branches. The fungus lives year after year within the tissues, and the injuries are gradually extended until the branch or even the tree may be killed. Spores are given off in the spring of the year from conspicuous orange-colored masses which grow out from

the diseased parts. These masses are sometimes mistaken for blossoms or fruit of the tree, and in some sections are known as cedar apples. They are moist and gelatinous in texture during damp weather, so that the first spores readily germinate where they are borne. These in turn give rise to minute secondary spores, which are readily blown about by the wind and which can only grow on some plant that is a member of the family to which the quince belongs. When they chance to fall on a quince tree, and the conditions are suitable for germination, rust is produced. The cedar apples become dry and withered during sunny weather, consequently the dissemination of spores is stopped until another rain softens the mass. Thus it happens that the period of infection may extend over a considerable length of time.

The spores that are borne on the quince trees can only grow when they in turn are carried to the cedars, thus starting new sources of infection.

There are a number of species of this fungus and all of them pass the second stage on some member of the same family of plants. The apple is sometimes attacked, and the service berry that grows in the foot hills and mountains is often badly diseased. Fig. 2, Plate VIII., is from a natural size photograph of a pear that was received from Glenwood Springs, Colo., August 29. A portion of its surface was covered with the spore bearing projections similar to those on the quince. It is an uncommon occurrence, however, for pears to be attacked by this fungus.

Experimenters usually agree that spraying with Bordeaux mixture has little effect in preventing this fungus from attacking fruit trees. They all recommend that the cedar and juniper trees in the vicinity of an orchard be destroyed, which of course is a certain remedy. But since orchard trees have been known to be infected from cedars eight miles away,* this method would not be practicable in Colorado. The quince growing sections of the State are mostly in close proximity to the foot hills and mountains, the sides of which are covered with extensive cedar forests. * Bailey cites an instance in New York, however, where the rust was much less abundant in sprayed portions of an orchard than it was on the unsprayed trees.

There are no records of experiments on the treatment of this disease in the arid regions, but since the dissemination of spores from cedar trees is dependent on the rain fall, it is not probable that the fungus will be so difficult to control as it is in humid climates. For this reason, also, it is not probable that the disease will be so abundant every year as it was last, since it is likely that a rain came at the time which was most favorable for the development and spread of the spores.

* Bailey, L. H., Cornell Univ. Ag'l. Expt. Sta., Bulletin 80.

However, if it is thought best to try to protect the quince crop, the following line of treatment is recommended: Spray thoroughly with Bordeaux mixture as soon as the fruit has set, and follow this with two or three more sprayings at intervals of ten days or two weeks. The young fruit should be protected with the mixture until the season of late spring and early summer rains is passed.

STRAWBERRY LEAF BLIGHT.

(*Sphærella fragariæ.*)

The illustration in Plate IX., Fig. 2, is from a natural size photograph of a strawberry leaf that was attacked by the common leaf blight or rust. This disease is so common and the characteristic spots which it produces on the leaves are so well shown in the illustration that an extended discussion of the nature and effects of the fungus will not be necessary. It may attack any portion of the plant above ground, and when the leaf surface is materially reduced, small berries are the result. The fruiting stems may be so injured by the fungus that the berries wither before they ripen, and when newly set plants are badly diseased, the future crop may be a failure. Some varieties are much more susceptible to attacks of this fungus than others, and some valuable kinds have to be abandoned in certain localities on this account.

The degree of susceptibility that a variety exhibits toward this disease varies in different localities, but good kinds may be found for every locality which are comparatively free from attacks of rust. Selection of resistant varieties is the most practical method of combating the disease, but it may be controlled by spraying with Bordeaux mixture if it seems desirable to do so. When setting new plants, all diseased foilage should be removed and destroyed, and the plants should be sprayed a few days after setting. The new growth must be protected with the mixture during the fore part of the season. This will require about four sprayings. The next season it is recommended that the plants be sprayed just before they blossom and again as soon as the blooming period is over. If the plants are to be fruited another season, the beds should be mown and burned over as soon as the picking season is passed. If the burning is properly done no harm will result to the plants, and many spores of the fungus will be destroyed.

WHEAT STINKING SMUT.

(*Tilletia fœtens.*)

It is the practice of the wheat growers in many sections of the State to treat their seed wheat with copper sulphate (blue vitriol), for

PLATE VIII.

Fig. 1. Quince attacked by rust fungus.

Fig. 2. Pear attacked by rust fungus.

Fig. 3. Apple injured by spraying with Bordeaux mixtures. All natural size.

PLATE IX.

Fig. 1. Plum leaves injured by shot hole fungus.

Fig. 2. Strawberry leaf attacked by blight. Both natural size.

the prevention of smut. The results of numerous experiments and the experience of many farmers prove that there is no doubt of the efficacy of the treatment. However, occasional failures are reported, some growers claiming that they can see no advantage in the treated over the untreated seed. Such results indicate that the best methods of treatment are not understood by all.

We intend to test the different ways of combating wheat smut in the near future, to determine which one is best suited to our conditions. In the mean time, the latest formulas recommended by the best authorities are given below:

I.

Copper sulphate (blue vitriol)	1 pound
Water	4 gallons

Dissolve the copper sulphate in hot water. Sprinkle or spray the solution on the wheat that has been placed in piles on the floor or on a canvas. Shovel the piles over while the liquid is being applied to insure the thorough wetting of every grain. Use no more of the solution than is necessary and spread out the piles so that the wheat will not remain wet long enough to become heated.

II.

Corrosive sublimate	1 pound
Water	50 gallons

To be applied in the same manner as the solution of copper sulphate.

III.

Formalin	1 pound
Water	50 gallons

Use the same as the other remedies.

Prof. Bolley, of North Dakota, who has experimented extensively with remedies for grain smuts, prefers the formalin treatment to any that he has tried.

FORMULAS.

BORDEAUX MIXTURE.

Copper sulphate	4 pounds
Lime	4 pounds
Water	45 gallons

The copper sulphate must be dissolved in hot water if wanted for immediate use. It may be dissolved by suspending it in a sack in the top of a considerable quantity of cold water, but this method requires a much longer time. If placed in the bottom of the vessel it will not all dissolve. The best quality of stone lime should be purchased, slacked and diluted till it is in the form of a thin whitewash. After the copper sulphate solution has been diluted to about thirty gallons, the whitewash is poured in, stirred thoroughly, and the mass diluted to the required 45 gallons. It is essential that both the copper sulphate solution and the whitewash be quite dilute before they are combined, otherwise a coarse precipitate is formed, which does not pass through the spray nozzles readily.

Where large amounts of Bordeaux are to be used, it is advantageous to keep on hand a stock of dissolved copper sulphate and of slacked lime. The stock of copper sulphate may be made by dissolving, say, fifty pounds in twenty-five gallons of water. Then one gallon of the solution will be equivalent to two pounds of copper sulphate, and two gallons will be required for a barrel of the mixture. The vessel containing the solution should be kept closely covered to prevent evaporation. It should be mentioned, also, that copper sulphate corrodes iron quickly, therefore it must not be allowed to come in contact with iron vessels or tools.

The lime may be slacked in quantities, when it will keep in good condition all summer, if it is not allowed to become dry. A chemical test for copper is taken advantage of to determine the amount of lime paste to be used. This is called the potassium ferrocyanide test. The chemical comes in the form of yellow crystals, and a few cents worth will suffice for the entire season. It should be dissolved in ten times its bulk of water when it is ready for use. A quantity of the lime paste in the form of a thin whitewash is added to the dilute copper sulphate solution, then the mixture is stirred thoroughly. A drop of the test is now allowed to fall on the surface of the mixture. It will instantly turn to a dark, reddish-brown color

if sufficient lime has been used. More lime must be added until the test shows no reaction, when the mixture is ready for use. A slight excess of lime will do no harm and will be a safe-guard against possible error.

Bordeaux mixture deteriorates rapidly, therefore it should be used on the same day it is made.

It is often desirable to apply poison to the same plants that are to be sprayed with Bordeaux. Fortunately the two remedies may be combined and both applied with one operation. Any of the arsenical compounds may be used, and at the same rate when mixed with water.

RESIN-BORDEAUX MIXTURE.

Recommended by * Sirrine for spraying asparagus, cabbage and other plants to which the common Bordeaux mixture does not readily adhere. Also as a poison carrier to make poison mixtures adhere to the same class of plants.

Resin	5 pounds
Potash lye	1 pound
Fish oil	1 pint
Water	5 gallons

Place the oil and resin in a kettle and heat until the ingredients are dissolved. Then remove from the fire, and when slightly cooled, add the lye slowly, while the mass is being continuously stirred. The water is now added and the mixture is boiled until it will mix with cold water, when it forms an amber colored liquid. Care should be taken at all times to keep the materials from boiling over and catching fire.

The above forms a stock mixture of which two gallons are used to forty-eight gallons of Bordeaux made in the usual manner. It is found best, however, to dilute the resin mixture with about eight parts of water before it was added to the Bordeaux.

The materials are used in the same proportions when Paris green or other similar poisons are being used on plants.

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* New York State Agri. Expt. Sta., Bulletins 144 and 188.

Bulletin 70. March, 1902.

The Agricultural Experiment Station

OF THE

Colorado Agricultural College.

Potato Failures.

A PRELIMINARY REPORT.

—BY—

F. M. ROLFS.

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POTATO FAILURES.

By F. M. ROLFS.

INTRODUCTION.

The following lines are written to call the attention of the potato growers in this state to a destructive disease of the potato, *Rhizoctonia solani* Kuhn. I am aware of the incompleteness of this report, but it is hoped that a publication at this time may stimulate an interest in the subject and thus call forth suggestions which will be helpful in working out a practical method of overcoming this disease. Undoubtedly this fungus has been common to the potato fields of America for years, and although of considerable economic importance it has been entirely overlooked by American investigators, and nothing of importance concerning its nature has been recorded. *Stewart and Duggar in 1901 published the first account of its occurrence in America.

European investigators have given it considerable attention and European literature contains a number of publications on a potato disease caused by *Rhizoctonia*. Its host plants cover a wide range and a number of species of the fungus have been described.

OCCURRENCE OF DISEASE.

The stem rot of the potato plant was first brought to my attention during the summer of 1900, while at the New York State Branch Experiment Station on Long Island. The potato growers in the various sections of the Island, complained of the early wilting or drying of the vines caused by a stem rot. On visiting these sections and making careful observations it was noticed that the disease in many instances resembled the stem rot of carnations, which is caused by the attack of a species of *Rhizoctonia*.

A microscopic examination of plants that had been recently killed invariably revealed an abundance of this fungus on the stems and roots. At least thirty plantations in various sections of the Island were visited and a number of dead plants from each field were carefully examined. Although other fungi were more or less plentiful on these stems, *Rhizoctonia* was constantly present both in the pith and on the outside of the roots and stems. These observations pointed toward the conclusion that this fungus had

* Bulletins 186 of the New York State Agricultural Experiment Station, and Cornell Experiment Station.

more or less influence on the death of the plants. The stems which had been dead for sometime were so completely overrun by other fungi that it was often difficult to identify the *Rhizoctonia* hyphae.

This Department has received many inquiries from potato growers in various sections of this State in regard to failures of the potato crop. Many of these inquiries gave a description of a diseased condition which is strikingly similar to the one that was so common on Long Island in 1900. After examining the tubers and stems from various parts of the state, it is quite evident that the fungus is common to nearly every section of this state, and especially abundant in many parts where failures occur. This information and the previous observations led us to believe that it is a parasite on the potato plant and that it probably had some influence on the failures recorded in these various sections. Accordingly the writer was detailed to take up this work and the results of the investigations and experiments are given in the following pages.

Our experiments prove that *Rhizoctonia* is an active parasite on the potato plant. Species of this fungus or possibly the same species occur on a great variety of plants among which may be mentioned the following: Beets, carrots, alfalfa, red clover, onions, turnips, peas, celery, lettuce, beans, cabbage, blackberries and raspberries. Usually it is a parasite but it is capable also of existing on dead organic matter in the soil and when favorable opportunities occur it invades and destroys the living tissues of plants.

The annual loss to the State from this disease is considerable. In many localities where potato growing was once a paying industry the soil has become so infected with the fungus that the crop is no longer profitable. Although it is more or less common to many fields, it apparently develops most rapidly in heavy soils which are poorly drained. The disease remains in the soil and grows worse with each succeeding crop, consequently failures are most apt to occur where a systematic rotation of crops is not followed.

Probably every state in the Union suffers more or less injury to its potato crop from this disease. It is known to be common to the fields of New York, Ohio, Iowa, Minnesota, Wisconsin, Florida, Oklahoma, Texas, Colorado, California and Washington.

EFFECTS OF THE DISEASE ON POTATO PLANTS.

In many sections of the State where potatoes are not successfully grown it is reported that large vines are pro-

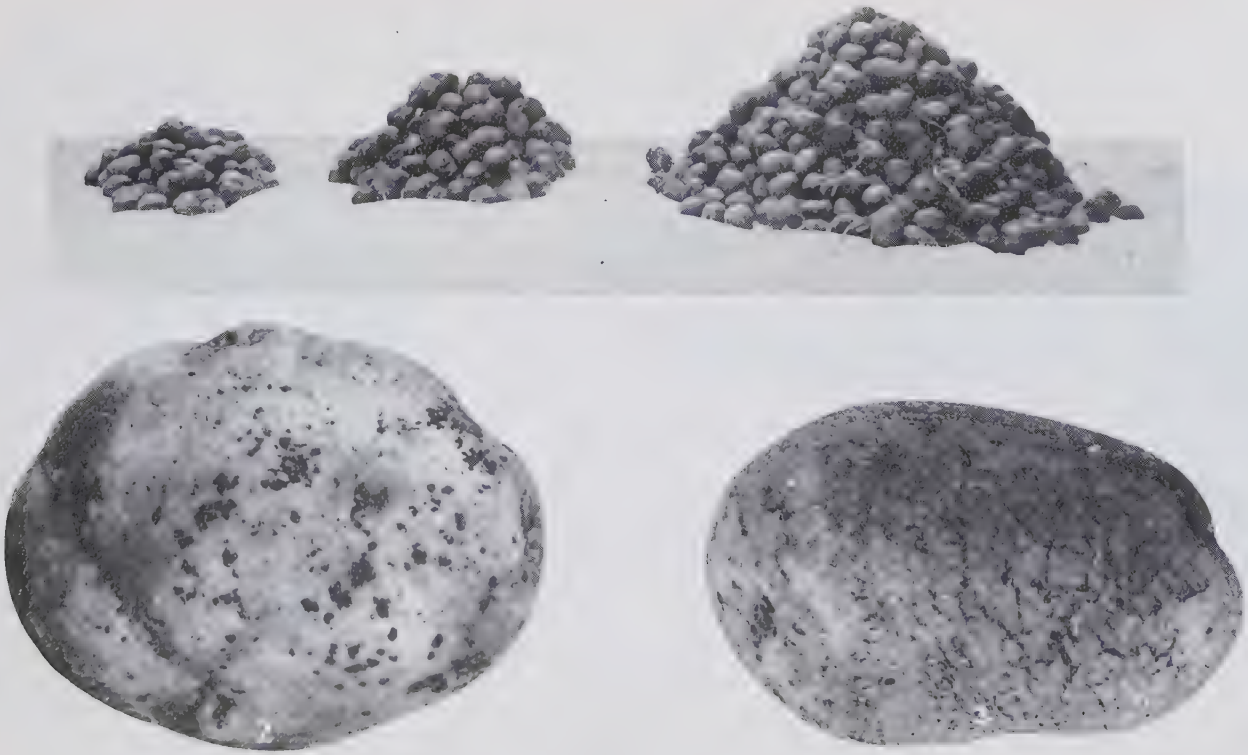
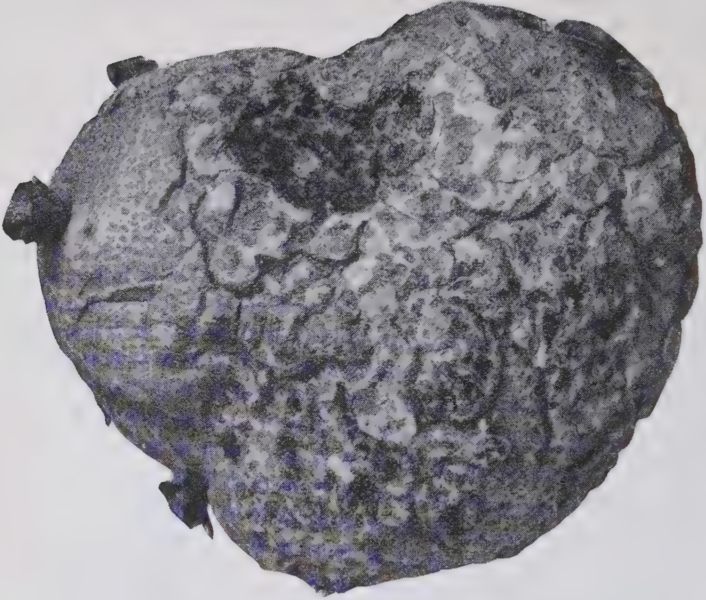


PLATE I.



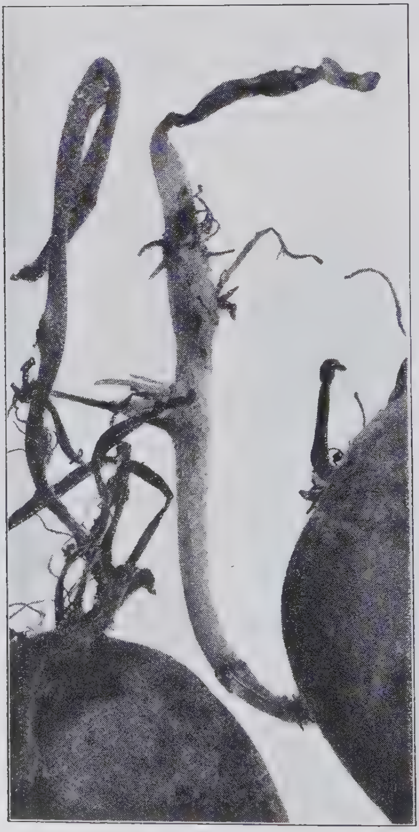


Figure 2.

PLATE II.

duced which give promise of an abundant yield, but when digging time comes it is found that so few tubers have set that it does not pay to dig them. Many of the thriftiest vines fail to produce a single tuber. (See Plate V.) It is a less frequent, but by no means uncommon occurrence, for the vines to set an abnormal number of small potatoes, or "Little Potatoes" as they are sometimes called. These often occur in compact clusters and are so small as to be worthless. (See Plate IX.) The above conditions occur most frequently on poorly drained land and especially on the heavier soils. A third condition and one which is common to the best potato districts is the dying of potato plants thus resulting in poor stands. Our experiments prove that any of these conditions may be produced by attacks of *Rhizoctonia*, and in the vicinity of Fort Collins, where most of our experiments and field work were done, this fungus is frequently responsible for the lack of success in the growing of this crop. So far as we have been able to learn, one or more of these conditions prevail in many sections where the potato crop is a failure.

The question naturally arises why this fungus should be so severe in its attacks on the potato at Fort Collins while the crop is so successfully grown in the Greeley district, twenty miles east and nearly the same altitude. Many farmers claim that if they had Greeley soil they could grow potatoes as successfully as those in the favored section. Our observations go to show that the difference between success and failure in potato growing is principally a difference in soils, not that the successful growers suffer no loss from the attacks of this fungus but that it finds less congenial surroundings in the lighter and better drained land.

NATURE OF THE FUNGUS AND ITS METHODS OF ATTACK.

The hyphae or root-like organs of the fungus are often found growing on the surface and in the scab ulcers of potatoes. These hyphae give rise to irregularly shaped dark masses know as sclerotia, which vary in size from that of a mere speck to areas one-half inch or more in diameter. (See Plate I. Fig 2.) The sclerotia resemble small bits of earth so closely that it is often difficult to distinguish them from particles of soil on the tubers, but by placing the potatoes in water these bodies become black and quite conspicuous. Many of them adhere very firmly. When such potatoes are used for seed the disease is planted with them and it is ready to begin its attack as soon as the new plants start to develop.

This disease like many other root fungi is greatly influenced in its growth by soil conditions. It may occur abundantly in the soil and on the seed potatoes and yet if the conditions are not favorable the plants may escape serious injury. On the other hand, a few diseased seed may cause considerable damage. The hyphae spread through the soil in various directions, hence a single diseased potato plant may be the means of infecting an area of considerable size, since the disease remains in the soil for a number of years.

Young plants are often severely injured by this fungus as shown in Plate III. Here two young shoots were killed before reaching the surface of the ground and the others were severely injured. Such wounds are usually characterized by a reddish-brown color and vary in size and shape.

Infected plants frequently show no marked signs of injury when first dug, but by leaving such plants in the collecting can over night the diseased parts take on a brown color and become quite conspicuous. Experience also shows that microscopical examination often fails to reveal the presence of the fungus if affected plants are not properly cared for after they are dug: therefore it is necessary to keep the plants in a fresh condition if they are to be successfully studied in the laboratory.

If the fungus produces wounds on the young plant that are small and confined to the outer tissues, the plant usually lives but it is apt to suffer more or less injury from the disease later in the season. The appearance of affected plants is familiar to many but the injury is usually attributed to such causes as altitude, dry weather, heat, over-watering, insect attack, blight and frost. Since conditions have a marked influence on the development of the disease there is some variation in the appearance of affected plants. Usually, however, there is no difficulty in its identification. Plants which are attacked while young, if not killed outright, are often dwarfed, take on an unhealthy appearance and frequently die long before the close of the season. On examining such plants one usually finds that the parts below ground are thoroughly infected with *Rhizoctonia* and often the pith of the stem is filled with this fungus. Such infections apparently start from diseased seed potatoes and the fungus grows up the stem, gradually killing the root system and finally starving the plant. (See plate VII.)

In some cases, the disease attacks the plant just below the surface of the ground, and if conditions are favorable for the development of the fungus, it produces a stem rot

PLATE III.

PLATE IV.

which is known in some sections as "Collar Rot" or "Black Ring" of the potato plant. Badly affected plants wilt suddenly and are soon dead and dry. Frequently, however, the attacks on the stem are not so severe but the wounds are so situated as to prevent the free transportation of plant food to the tuber stems, thus cutting off the food supply to the growing potatoes, which consequently remain small. If the injuries prevent the assimilated food from being stored in the subterranean parts of the plant, large tops are produced, and green tubers often form in the axils of the leaves, thus giving rise to the so-called "Aerial Potatoes". (See Plate VIII.) When the root system of such plants is more or less injured, the leaves usually take on a lighter color and have a tendency to fold. The stems become thicker, and grow prostrate, giving the plants a bushy appearance.

A similar condition is brought about by the attacks of the fungus on the tuber-stems. Young tubers are frequently cut off by the fungus as shownin Plate XI. Fig 2. The yield is often materially reduced in this way and it is not uncommon for all of the tubers to be cut off as shown in Plate VI.

When the tuber stems are less severely injured, but the wounds are severe enough to interfere with the flow of plant food to the young potatoes, the buds on these stems just above the wound often develop tubers. But the fungus may continue its work and again injure or cut off the stem above the newly formed tubers. When the main stem is infected with the disease, the tuber-stems are apt to be cut off before they have made much growth. In such cases blind or adventitious buds may push out and form on the main stem around the injured member and develop short-stemmed or stemless tubers as shown in Plate IX. where a typical cluster of "Little Potatoes" have formed. If the root system is also invaded by the disease, the vitality of the plant is reduced and it puts out few or no subterranean stems. The tuber-stems which do grow are probably weak and soon cut off by the fungus. Such plants set few or no tubers and usually take on the peculiar top development described above.

INOCULATION EXPERIMENTS.

The following series of inoculation experiments was undertaken with cultures of *Rhizoctonia* to prove that the disease is parasitic and that its attack on the potato plant may produce the conditions described above. Pure cultures were readily obtained from the sclerotia on tubers. Conditions have a marked influence in the growth of this fungus in the

laboratory as well as in the field; dryness and exposure to sunlight are especially liable to check its development. Test-tube cultures are very sensitive, hence results from inoculations are apt to be misleading, since the culture material may be weak or dead when the inoculations are made, or the conditions under which the plants are growing may be unfavorable for the best development of the fungus.

These experiments were conducted in the field with the exception of No. 2. *Check plants were used in the experiments and all of them remained in a healthy and vigorous condition.

No. 1. On August 24 placed pure cultures of this fungus on twenty tuber stems and carefully covered the inoculations with grafting wax. In this experiment long young stems were selected in order to be able to make the inoculations some distance from the main stem. On August 29 eight of these stems were examined. All of them had brown-colored areas on inoculated surfaces. September 10 examined the remaining twelve stems. Seven had deep scars under the wax and five of these seven developed new tubers above the wound. The remaining five inoculations gave no marked results.

No. 2. July 7 inoculated twenty green stems on plants growing in pots in the greenhouse. Small incisions were made and particles of the culture material inserted. Check wounds were made in the same manner but not inoculated and all wounds were covered with grafting wax. August 21 three of the inoculated stems were found to be cut in two, eleven were deeply scarred and six remained uninjured. Plate XII. shows four stems taken from this lot.

No. 3. Twenty inoculations made September 18 in the same manner as No. 1. Six of the inoculated tuber-stems were killed and the plants produced stemless tubers. Out of six root-inoculations four were killed and two remained healthy. Two of the eight inoculated branches were injured and six remained sound.

No. 4. August 31, inoculated seven stems just below the surface of the ground. The operation was performed as in No. 1. These inoculations were examined September 12. Three produced a distinct black ring around the stems and four gave no marked results.

No. 5. On the same day, August 31, fifteen tuber-stems and five roots were treated in the same way as in No. 1. These inoculations were made close to the main stem. September 12 five stems and the five roots were examined. All inoculations produced brown-colored areas on the inoculated surfaces. September 22 the remaining ten of these inoculations were carefully examined; seven of these had developed deep black wounds under the wax. The remaining three were completely cut off and small stemless tubers had developed on the main stem around the injured tuber stem. More or less of *Rhizoctonia* hyphae were found in all of the wounds.

No. 6. On August 15th twelve green stems were slightly injured with a sterilized knife, and pure culture of the fungus was placed in the wounds and the inoculations were covered with wax. A careful examination of these stems was made on September 6. Three of them were killed. (See Plate XI. Fig. 1.) Six developed marked wounds and three were healthy. Hyphae of the fungus were more or less plentiful in all of the wounds. The five check injuries healed and the stems remained vigorous.

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* In any inoculation experiment it is necessary that uninoculated plants be grown under the same conditions for the sake of comparison. In the following discussion such plants are designated as checks.

PLATE V.

PLATE VI.

7. On August 1st, pure culture of the fungus was placed on five tuber-stems and the cultures were covered with wax. These stems were examined on August 15th, and it was found that the fungus had produced marked wounds on all of them. Two of these stems which were practically cut off are shown in Plate XI. Fig 2. Two of the five stems used for a check were slightly colored under the wax but no traces of the disease were found.

These experiments show that the attacks of the fungus may produce the abnormal development of the potato plant, so common to many of our fields.

It is evident if fungus injuries are responsible for such peculiar development of the plant that mechanical injuries ought to produce similar results. Accordingly a series of experiments was planned tc test these points.

Mechanical Injuries. On August 24th, all of the tubers were removed from forty plants. September 2d, the tubers which had formed during this time were removed and many of the roots were injured. All the plants soon took on the peculiar development described above and 29 of them developed "Aerial Potatoes." These plants were dug September 20 and it was found that many of them had produced typical "Little Potatoes." (See Plate X.) Examinations failed to reveal the presence of *Rhizoctonia* on any of these plants. Check plants growing by the side of those used in the experiment produced normal tops and tubers.

On the same day, a ring of outer tissue about one half-inch wide was removed from around the main stem of twenty-five plants. These plants also took on the peculiar top development and all produced aerial tubers. Plate IX. shows a fair specimen of this lot of plants. Twisting the stem and wrapping a wire firmly around the stem gave similar results.

THE SEED.

During the past spring, the Department made a number of observations on the percentage of infected *Rhizoctonia* tubers in different lots of potatoes offered for sale as seed. One lot examined contained 805 tubers. Ninety-one per cent of these were infected with the disease and were more or less covered with sclerotia. While the remaining nine per cent were free from the sclerotia, careful examination with the microscope revealed the fact that the eyes of most of these tubers harbored a few strands of the fungus. Five of the supposed clean potatoes were placed in a moist chamber and at the end of two weeks, there was an abundance of this fungus on three of them. The other two were completely overrun with *Fusarium* and no traces of *Rhizoctonia* could be found. The

amounts respectively of clean and diseased potatoes in this sack are shown graphically in Plate I. Fig 1.

From another lot of potatoes which had been in sacks for some time 549 pounds were carefully examined. Fifteen per cent were free from disease, so far as could be determined, and 85 per cent were infected. Many of the sprouts had been overrun with the hyphae, and sclerotia had been developed freely on both sprouts and tubers. (See Plate IV.) Some of the sprouts had been completely cut off; the tips frequently suffered most severely, and the ends of many of the sprouts were dead and dry. (See Plate II. Fig. 2.)

Fifteen of the diseased tubers were placed in moist chambers. Five of them developed sclerotia on tubers and sprouts. The fungus on the remaining ten was apparently dead, and no further development took place. These potatoes were carefully watched and examined from time to time. Apparently the development of the disease ceased soon after they had been removed from the sack. Exposure to the dry air and sunlight probably killed the fungus. Experiments and observations indicate that excessive drying and sunlight kills the hyphae and sclerotia which grow on the surface of potatoes, and that the hyphae which grow in the deeper wounds are probably not much influenced by such treatment.

Potatoes from these lots early in the season gave a much lower percentage of infection. In neither case did it exceed thirty per cent. In the lots examined during the winter before the tubers were placed in sacks, the proportion was usually low, and seldom exceeded twenty per cent.

It is evident that under favorable conditions infected potatoes develop hyphae and sclerotia freely after being stored. A few diseased potatoes in a bin or sack of clean ones, under suitable conditions will spread the disease, and in a short time may render the entire lot worthless for seed.

The cracked skin and rough surface on so many potatoes from diseased fields, led us to suspect that *Rhizoctonia* had more or less influence in bringing about this condition and the constant association of this fungus with these injuries also pointed strongly toward this conclusion.

Observations show that the hyphae frequently enter the lenticells of the tubers and produce corroded spots, or minute open pustules. In rapidly growing tubers such openings are often extended, producing numerous cracks which frequently become confluent. These cracks are repaired by a natural effort frequently producing a peculiar corky, or apparently a double skin on the potato as shown in Plate I. Fig 3.

PLATE VII.

PLATE VIII.

And if the fungus continues its attacks, or if other fungi invade the injured parts, repeated efforts are made to repair the damage, and the surface of the potato may be brought into a rough or cracked condition, giving it an unsightly appearance. An extreme case of such injuries is shown in Plate II. Fig 1. That *Rhizoctonia* is the cause of this condition is proven by the following simple experiment.

On September 11, 1901, small amounts hyphae from pure cultures of the fungus were placed on the surface of eighteen small growing potatoes and covered with sterilized grafting wax. On September 25th, two of these potatoes were examined and a number of brown spots were observed on the inoculated surfaces. By a careful microscopic examination it was found that the hyphae had entered the lenticells and produced a small rupture in the skin. On September 26th, a third inoculated tuber was examined and a number of cracks each starting from a lenticell were observed. On October 10th, the remaining fifteen tubers were examined and it was found that ten of these had developed sclerotia abundantly, and the entire covered surface was a net-work of cracks. Two of the remaining five had each a deep crack extending across the tuber. All inoculations produced brown rough surfaces. An abundance of the fungus was found on each tuber, while the five checks which had been treated in the same way with the exception of adding *Rhizoctonia* culture, remained free from cracks.

METHODS OF TREATMENT.

It is difficult to treat this disease, since the external characters usually do not appear until the tissues of the plant are thoroughly invaded with the fungus. Applications of fungicides to affected plants would have little or no influence on the disease. Under favorable conditions the fungus spreads rapidly through the soil in various directions. There is no practical method of checking its spread after it is once introduced into the soil. The only way of dealing with it is by preventive means. From the nature of this fungus, it is evident that diseased seed potatoes are frequently the means of introducing the disease into clean fields; hence, too much care cannot be exercised in selecting clean seed. But even then, the potatoes are apt to harbor the fungus if they have been in contact with infected tubers. Danger from this source may be largely overcome by the treatment given on page 12.

The disease may be carried on beet roots, or dead potato stems or on the dead stems of many of the weeds which grow in the potato fields. Infected potato and weed stems often find their way into the barn-yard and compost heap, thus manure may become a source of general infection to clean fields. Great care should be taken to keep diseased plants and tubers out of the manure. The burning of all vines and weeds, as soon as the potatoes are harvested, is an excellent practice.

Some fields seem to be more favorable for the development of this fungus than others. A heavy poorly drained field seems to be of the favoring class. A thorough drainage of the land would probably do much good. Potatoes grown on heavy soils with good bottom drainage usually suffer less severely from the disease than those grown on poorly drained soils. It is not definitely known how long this disease will remain in a field when it once becomes thoroughly established, but it is quite evident that land on which diseased potatoes have been grown usually harbors the fungus a number of years, hence, it is important to follow a systematic rotation of crops, and it will probably be necessary to follow a five-year rotation in order to obtain good results.

"Prunet * believes that the fungus remains in the soil three years, and recommends that diseased fields should not be cropped with lucern or clover for several years. Evidences indicate that root crops should be avoided. Cereals which are probably not attacked by *Rhizoctonia* should be sown in the infected ground, and all weeds should be kept down. This is probably the only means by which the fungus can be destroyed."

Corrosive Sublimate Treatment. Corrosive sublimate or bichloride of mercury is sold in form of white crystals. It may be bought at any drug store for about fifteen cents an ounce. The cost of material for treating the seed for an acre will not exceed fifty cents. The solution is made by placing one ounce of this chemical in an earthen or wooden dish containing one gallon of hot water. As soon as it is all dissolved pour the contents of the dish into a wooden vessel containing seven gallons of water. Put the potatoes into this solution, and let them remain an hour and a half. The solution may be used a number of times. The disinfection may be done at any time. Experiments indicate, however, that treating the tubers about a week before planting, and spreading them on the floor or ground where they will be fully exposed to the sunlight, greatly facilitates their growth after planting. *Corrosive sublimate is a deadly poison to both man and animal when taken internally*, but the solution and treated potatoes may be handled freely without experiencing any ill results.

FORMULA.

Corrosive Sublimate	1 ounce
Water	8 gallons.
Soak Potatoes	1½ hours.

*(Prunet "Sur le *Rhizoctonia* de la Lucerne". Compt. rend. Paris 1893.

PLATE IX.

PLATE X.

Formalin Treatment. Formalin is sold in the form of a liquid at about fifty cents a pint. It is a little more expensive than corrosive sublimate but has the advantage of not being poisonous, comes in form of a liquid, and can be used in any kind of a vessel. The solution is made by adding one half-pint of formalin to fifteen gallons of water. The tubers are placed in this solution for two hours. This treatment does not retard the sprouting of the tubers, and it may be used at any convenient time before planting. If the tubers are treated during the winter, they should be dried and carefully stored avoiding all danger of reinfection from infected sacks and bins. The solution loses strength on standing, and must be kept in a closed receptacle if it is to be used a number of times. It is probably not best to use the solution for more than four successive treatments.

FORMULA.

Formalin	8 ounces (½ pint.)
Water	15 gallons.
Soak Potatoes	2 hours.

Keeping Seed Potatoes. It is evident that the success of the potato crop depends much upon the vigor and condition of the seed potatoes. Some growers have adopted the following practice with excellent results: When the potatoes are dug, those which are to be used for seed are stored in a dry, dark shed or barn until about the 10th of November. Just before freezing weather sets in, the potatoes are carefully sorted, and those which show the slightest signs of decay are rejected. A layer of straw from eight to ten inches thick is spread on the ground and the tubers placed upon this straw. The piles should not be made too large. The best results are usually obtained from mounds three feet wide at the base and piled up in ridges as high as convenient. A covering of straw is placed over the potatoes, and this is followed by a layer of soil from six to eight inches thick, but before severe weather sets in more soil is added, and when the severest weather is at hand, more straw, or strawy barn manure is added. The aim is to cover gradually as the cold increases. This method of storing potatoes seems to winter them much better for seed than when they are placed in root cellars, or when they are stored in mounds immediately after they are dug. About the last of April they are taken from the pit and again stored in a dark shed or barn until about ten days before planting-time when they are treated with corrosive sublimate, as given in formula on page 12. After this treatment they are placed where they will be freely exposed to the sun. Seed should not be cut until shortly before planting. If

planting is delayed, the cut pieces should be placed in a moist, cool place.

EXPERIMENTS IN TREATING SEED POTATOES.

Greenhouse Experiments. The following experiments were conducted in the greenhouse to get some hints on the value of treating infected tubers with corrosive sublimate:

Experiment I. The first experiment was with sixteen pots filled with sandy, clayey soil which was thoroughly infected with the disease. The soil in eight of these pots was sterilized two hours a day for three consecutive days, and planted with apparently healthy seed which had been placed in a solution of one ounce of corrosive sublimate to eight gallons of water for one and one-half hours. All tubers produced healthy and quite vigorous plants which lived until the experiment was closed. Careful examinations showed that all but one of these plants were free from disease. This infection was probably due to carelessness in watering the plants with a hose, since pots containing treated and untreated soils stood side by side. The soil in the other eight pots was not sterilized, and planted with clean tubers, treated in the same manner as those in the first lot. The potatoes all grew, but the plants did not do so well as those in the first lot, and three of them died shortly before the experiment was closed. On examination, it was found that all the plants were infected with the disease. A number of sclerotia were found on four of the tubers.

Experiment II. The second experiment contained twelve pots of heavy black loam which had been used in growing Alternanthera in the greenhouse during the preceding winter. The soil in the first four pots was not sterilized and was planted with tubers on which there were numerous sclerotia. These tubers were treated with one ounce of corrosive sublimate to eight gallons of water for one and one-half hours. The plants did quite well, but careful examination showed that all were more or less affected with the disease. The soil in the next four pots was sterilized two hours a day for three consecutive days, and planted with seed treated in the same way as those in the preceding lot. These plants made good growth and lived until the experiment closed. Critical examination failed to reveal any traces of the disease. The soil in the last four pots was treated as in the second lot, but was planted with infected tubers. One tuber failed to grow. Two produced weak plants which died prematurely and the fourth plant did poorly, but lived until the experiment closed. All plants were infected with *Rhizoctonia*.

Experiment III. In the third experiment, thirty diseased tubers were planted in a bench containing three inches of potting sand on the bottom and four inches of sandy clay loam on top. The first lot contained fifteen tubers which were treated with one ounce of corrosive sublimate to eight gallons of water for one and one-half hours, and planted twelve inches apart. These plants were slow in reaching the surface of the ground, but otherwise, they did nicely, and remained green until the close of the experiment. Thirteen of these hills, containing fifty-seven plants, were free from the disease, and only one plant in each of the other two hills, containing eight plants, was infected. It is possible that this was due to soil infection. In the second lot used in this experiment, the tubers were not treated, otherwise the conditions were much the same as in the preceding. Some of the plants soon reached the surface of the ground; others, however, were considerably delayed, and a number were killed before reaching the surface. Those which finally became established did quite well apparently, but twelve of the hills, sixty plants, died two weeks before the experiment was closed, and all were covered with an abundance of *Rhizoctonia* hyphae. The other three hills, fifteen plants, lived, but a careful examination showed that all of them were more or less affected with the disease.

These experiments show that diseased potatoes may be readily disinfected with the corrosive sublimate. But in or-

der to obtain good results the treated seed must be planted in soil which is free from the disease.

Field Experiments. Encouraged by the promising results in the greenhouse experiments, although somewhat late in the season, we concluded to try the treatment on a larger scale. Accordingly arrangements were made with Mr. J. G. Coy of Fort Collins, to carry on an experiment on his farm, in which he kindly consented to assist us. The soil of the field selected for the experiment was of heavy black loam on the river bottom. It was afterwards found that the level of the soil water was comparatively close to the surface. It had been flooded by late rains, and was too wet to get in shape for planting before June 6th. Most of the ground had been planted alternately with cabbage and onions during the past five years. It is quite probable that the soil contained more or less of the fungus since onions which remained in the field from last year's crop were badly infected. Potatoes grown on this place have suffered more or less from early blight for a number of years.

This field was divided into four plots. The rows were twelve rods long and planted in the usual way. All four plots were planted with Wisconsin seed of the Pearl variety. These tubers were infested with *Rhizoctonia.* Plots I., III. and IV. were sprayed with Bordeaux mixture, and Paris green on July 7th, 17th, 31st and August 15th. The seed of Plots III. and IV. was treated with corrosive sublimate as given on page 12. The seed of Plots I. and II. was not treated. The rains during the fore part of the season kept the ground sufficiently moist for the growth of the plants and the field received its first irrigation on August 13th. From this time on the ground was kept quite moist. The potatoes were dug October 10th.

Plot I. This plot occupied the lowest and most poorly drained part of the field. The seed of this lot was not treated, but the plants came up nicely, and most of them looked promising during the early part of the season. They were sprayed thoroughly four times, and remained green until killed by frost. Joining this plot was a garden patch of potatoes which was badly infected with the *Rhizoctonia.* The leaves of these diseased plants soon took on a lighter green color, had a tendency to fold, the stems became heavier, their internodes remained short, and in many of the plants, grew prostrate. These tops were soon invaded and completely ruined by early blight. During the later part of July, it was observed that a number of the plants in the rows joining the garden patch were taking on an abnormal top development. After the first watering, this peculiarity became prominent on many other plants, and at the close of the season, it is doubtful if there was a single plant in the entire plot which had a normally developed top. On August 10th, a careful examination was made of fifty plants taken from various parts of this plot, and it was found that the hyphae of *Rhizoctonia* occurred most abundantly on the plants in the first three

rows joining the infected patch. Apparently the disease gradually spread from the infected soil. Most of the plants in this plot developed small tubers and some of them grew no tubers at all. From eight rows one hundred and forty pounds of rough, corky potatoes were gathered. In some cases the plant apparently failed to put out tuber stems, while in others, the stems which were put out had been injured or completely cut off, producing Little Potatoes, and a number of the plants produced Aerial Potatoes. On October 10th, it was impossible to find a plant in the plot which was not more or less affected with the disease. The root system was also abnormally developed. It too showed the effects of the disease. The younger roots and root tips suffered most. Many of them were dead, and a careful examination of the living and recently killed parts showed the presence of an abundance of *Rhizoctonia* hyphae.

Plot II. was used for check. The seed of this plot was not treated, and the plants were not sprayed. They came up nicely, but some of these blighted early and many of them were killed fully two weeks before frost. It was found on examination, that many of these plants were more or less affected with *Rhizoctonia*. Nine rows yielded 1128 pounds of tubers, which averaged 94 pounds per sack.

Plot III. was planted with the roughest and poorest tubers of this lot of seed. They were treated with corrosive sublimate one day before planting but only about three-fourths of the tubers grew, and the plants were unusually slow in reaching the surface of the ground. This plot was sprayed four times. Diseased plants were less plentiful in this plot than in the preceeding. Seven rows produced 910 pounds of tubers, giving a gain of 4 per cent over check. These tubers averaged 102 pounds per sack.

Plot IV. The seed of this lot was treated with corrosive sublimate one day before planting. The plants were fully five days later in reaching the surface of the ground than those of Plot II, but four weeks later there was very little difference in the size of the plants between the two lots. These plants were sprayed four times which kept their foliage in an excellent condition, until injured by frost. Fifteen rows yielded 2,625 pounds of clean, smooth tubers, giving a gain of 40 per cent over check. It is quite evident that this gain would have been considerable more had the frost been a month later. The tubers averaged 106 pounds per sack.

For the sake of comparison, the methods of treatment and the yields of the different plots are given the following table.

TABLE I. RESULTS IN TREATING SEED POTATOES.

Plot.	No. of rows.	Treatment of seed.	No. times sprayed.	Yield per row in lbs.	Gain over plot No. 2.	Average lbs per sack.
No. 1	8	None.	4	17½	861 loss.	
No. 2	9	None.	None.	125⅓	———	94.
No. 3	7	Corrosive sublimate.	4	130	4	102.
No. 4	15	Corrosive sublimate.	4	175	40	106.

The results of these experiments may be briefly explained as follows: The poor yield in experiment No. 1, may be accounted for by the fact that the plot was situated by the side of a badly infected garden, where potatoes had been grown for several years. It is probable that the disease spread through the soil from the infested patch. (The result of this experiment cannot be considered for this reason.)

PLATE XI.

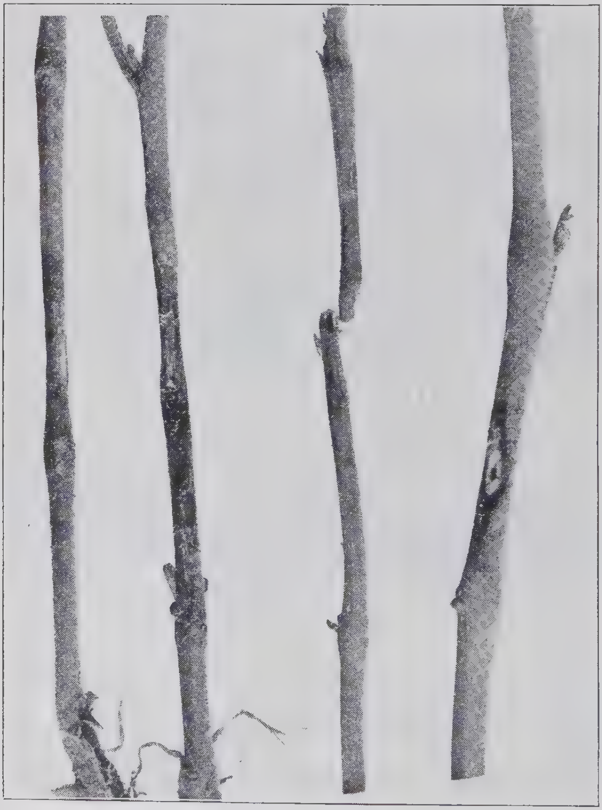

PLATE XII.

In Plot No. III. poor seed was selected which was treated with corrosive sublimate. That only three-fourths of a stand was secured was undoubtedly due to weak seed. The slight gain over the untreated seed indicated that in any method of treatment, it will pay to carefully select the seed potatoes.

The seed potatoes used in Plot No. IV. were of the same quality as those used in Nos. 1 and 2, and were treated with corrosive sublimate. The plants were sprayed four times. The results show a gain of 40 per cent over the untreated seed in Plot No. II.

The difference in the average weight of sacks of potatoes of the same size from different plots is interesting; the potatoes from Plot No. 4 averaging 12 pounds more to the sack than those grown in check Plot No. II. No explanation for this difference is offered at this time.

These experiments show that early blight can be held in check with Bordeaux mixture if the spraying is commenced early, and done thoroughly, but it is probably a waste of time and material to spray plants badly infected with *Rhizoctonia*.

FUTURE INVESTIGATIONS.

Different varieties of potatoes vary considerably in their susceptibility to disease when grown under the same conditions. It has been observed frequently that of plants of different varieties grown in the same hill, and probably equally exposed to infection, some will die early in the season, and produce no tubers at all, while the others will live to the end of the summer and produce a fair yield. Even plants of the same variety often show considerable difference in power of resisting the disease. The cause of such resistance will be studied, and it is hoped that in time a number of hardy or disease resistant varieties may be produced.

The best method of treating and wintering the seed is receiving careful attention, and it is believed that bin and sack infections can be largely prevented.

Some sections seem to have much trouble with the running out of potatoes. The indications are that this condition may be overcome, in some cases at least, but it will be necessary to repeat the experiments another year before making a report.

Field observations indicate that *Rhizoctonia* frequently produces a rot of potato tubers. However, only two tubers out of more than one-hundred inoculated in the laboratory gave marked results, but many were slightly decayed.

These negative results may have been due to unsuitable conditions. A thorough study of this phase of the disease will be made during the coming season.

From a number of observations during the year, it is quite evident that the *Alternaria* which infest the onions of this section may also invade the foliage and produce early blight of potatoes. Hence it was found necessary in the field experiments to spray the plants with Bordeaux mixture as a preventive of this disease. Further observations may show that early blight is an important factor in producing potato failures in some sections. Should this prove to be true it may be controlled with Bordeaux mixture. Onions also frequently harbor *Rhizoctonia.* This probably explains why potatoes so frequently do poorly when planted in onion ground.

Experiments during the past year indicate that sulphur has very little or no value in treating this disease. Lime may prove helpful. Both sulphur and lime will be given a thorough test during the coming season.

Preliminary experiments in rejecting all infected seed potatoes gave excellent results.

ACKNOWLEDGEMENTS.

In conclusion I wish to offer my sincere thanks to Prof. Paddock who has made many helpful suggestions in this work. The illustrations of this bulletin were all taken and arranged by him. I am also indebted to Mr. J. G. Coy of Fort Collins, for his co-operation in the field experiments.

SUMMARY.

Rhizoctonia solani (Kuhn) is the name given to a fungus which occurs on the underground parts of the potato plant. Our experiments show that this fungus is an active parasite on the potato and that it is one of the principal causes of potato failures in many parts of the state.

Many potato growers are familiar with one or more of the following conditions which have usually been thought to be due to the influence of altitude or climate; abnormally large vines which produce few or no potatoes, (See Plate V.) vines which though vigorous in appearance, bear a large number of small, worthless tubers, (See Plates IX. and X.) The failure of much of the seed to grow or the dying of plants during the fore part of the season resulting in a poor stand, (See Plate III.) This fungus, in the vicinity of Fort Collins at least, frequently produces all of these conditions.

The fungus lives over winter on the potatoes in the form of dark patches which resemble bits of soil (See Plate I. Fig 2.) When such potatoes are planted the fungus develops with the plant and begins its attacks at once.

When a field has become thoroughly infected with the disease it will remain in the soil a number of years.

The nature of the disease indicates that it may be combatted by preventive means which consist in planting clean seed in clean soil. Seed potatoes should be carefully sorted, disinfected and planted on land that is well underdrained. Then by practicing a long and systematic rotation of crops, the soil may be prevented from becoming badly infected with the disease.

The fungus may spread from a few diseased potatoes in a sack or bin and in a short time render the entire lot worthless for seed.

In our experiments diseased seed potatoes treated with corrosive sublimate and sprayed with Bordeaux mixture gave an increase in yield of forty per cent over untreated seed and unsprayed plants. The soil used in the experiments was heavy, poorly drained and infected with *Rhizoctonia*. A lighter, well drained soil free from the disease undoubtedly would have given still better results. The formalin treatment also gave encouraging results.

EXPLANATION OF PLATES.

PLATE I. FIG. 1. Sack of potatoes examined June 3. Large pile contains badly diseased potatoes, slightly diseased in the center, while the smallest pile contains the clean potatoes.

FIG. 2. Sclerotia of *Rhizoctonia* on potato. Very common on seed potatoes.

FIG. 3. Surface of potato covered by net work of fine cracks caused by attacks of *Rhizoctonia*. Figs. 2 and 3 natural size.

PLATE II. FIG. 1. Potato badly scarred by *Rhizoctonia*. Much of the so-called scab is undoubtedly due to this disease.

FIG. 2. Potato sprouts killed in the sack by the fungus. From the sack shown in Plate I. Both figures natural size.

PLATE III. Showing how *Rhizoctonia* attacks young plants in the field. Two on the right were killed before reaching the surface of the ground. The others badly injured. Natural size.

PLATE IV. Potato sprouts from sack. Some killed by and others showing sclerotia of *Rhizoctonia*. Enlarged.

PLATE V. Plant from which potatoes were all cut off by *Rhizoctonia*, producing an abnormally large top.

PLATE VI. Large vine from which all but a few small potatoes were cut off by the fungus.

PLATE VII. Potato plant infected from diseased seed; the root system badly injured.

PLATE VIII. Potato plant from which the tuber stems were all cut off by the fungus. As a result a large top was produced and tubers formed in the axils of the leaves.

PLATE IX. "Little Potatoes" and "Aerial Potatoes" produced by ringing the main stem. August 24.

PLATE X. "Little Potatoes" and "Aerial Potatoes" produced by removing all potatoes twice during the season. August 24 and September 2.

PLATE XI. FIG. 1. Three green potato stems inoculated with cultures of *Rhizoctonia*. One completely cut off, the others nearly girdled.

FIG. 2. Two tuber stems inoculated as above. Both cut off by the fungus at the discolored point. All natural size.

PLATE XII. Green stems inoculated with cultures of *Rhizoctonia*. One cut in two, the others badly injured. Natural size.

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INSECTICIDES.

INSECTICIDES. (Preparation and Use).

Substances that Kill by Being Eaten.

1. White Arsenic.
2. Arsenic Bran-mash.
3. Paris Green.
4. Scheele's Green (Green Arsenoid).
5. Arsenate of Lead.
6. Arsenite of Lime.
7. London Purple.
8. Bordeaux Mixture.
9. White Hellebore.
10. Borax.

Substances that Kill by External Contact.

11. Soap.
12. Whale-oil Soap.
13. Fish-oil Soap.
14. Kerosene Emulsion.
15. Kerosene-milk Emulsion.
16. Kerosene and Crude Petroleum.
17. Gasoline.
18. Turpentine.
19. Lye and Washing Soda.
20. Lime.
21. Lime, Salt, and Sulphur Wash.
22. Resin Soap (Summer Wash).
23. Resin Soap (Winter Wash).
24. Pyrethrum or Buhach.
25. Tobacco.
26. Sulfur.
27. Hot Water.
28. Carbon Bisulfide-"Fuma."
29. Hydrocyanic Acid Gas.

Substances that Repel.

30. Napthaline, Gum-camphor and Moth-balls.
31. Tobacco.
32. Ashes.
33. Lime, Plaster, and Road Dust.

Insect Traps.

34. Lights.
35. Sweetened Water, Cider, Vinegar, Etc.
36. Bandages.
37. Hopper-dozers or Hopper-pans.
38. Sticky Substances.

THE APPLICATION OF INSECTICIDES:
In the Dry Way.
In the Wet Way.
Pumps.
How to Spray.

INSECTS AND INSECTICIDES.

C. P. Gillette.

Bulletin 47, treating of "Colorado's Worst Insect Pests and Their Remedies," is out of print. As there is much demand for a bulletin of a general nature treating of the insects that are most injurious in Colorado, and the methods by which they may be destroyed or kept in check, the present publication has been prepared. In the first part of the bulletin, dealing with insects injurious to Colorado fruits, it has been the plan to treat the more common insects only, and to treat each as briefly as possible and still give the necessary information to enable the farmer or horticulturist to decide what insect is doing the injury in a particular case, and what remedies he should use. The object of the second part of the bulletin, treating of the "Preparation and Use of the More Important Insecticides," is well stated in the title. Many substances that are rarely used, and others which are of little or no value, are not mentioned.

The insecticides are numbered in the order in which they are taken up. They are also referred to by number in the first part of the bulletin, which makes it easy to refer to them. When more than one remedy is mentioned, they are given in the order of their preference.

PART I.

INSECTS INJURIOUS TO THE APPLE.

ATTACKING THE FRUIT.

CODLING MOTH.

Flesh-colored larvæ eating into the fruit and causing wormy apples. The first brood of larvæ (worms) begin eating into the fruit when early apples are about an inch in diameter. This brood is not very numerous, but it develops into a second brood about seven weeks later which is very much more numerous. The moth and its eggs are shown at Plate I., Figs. 3 and 4.

Remedies.—The arsenical poisons are, by far, the best remedies we have for this insect. See remedies 4, 3, 6, 8, 7, 5.

The combination of Bordeaux mixture (8) with the arsenites is very popular farther east where fungus diseases are prevalent. The writer believes there is no occasion as yet to use Bordeaux mixture upon apple trees in Colorado except for the purpose of causing the poison to adhere better to the foliage.

Make the first application as soon as the blossoms have faded and nearly all fallen. Continue the application till every calyx (blossom) is filled with the liquid. Repeat the application in one week. If heavy storms follow to wash out the poison, make a third application as soon as the storm is over. Upon the thoroughness of the first and second applications the success will chiefly depend. Just what degree of success may be expected from later applications has not been thoroughly determined. *Professor Cordley, of Oregon, seems to have proven that late spraying is very important in that State.

Bandages (36) are also of considerable service if carefully attended to. Lights to trap the moths are valueless. Screen cellar windows and doors where fruit is kept.

Plate II., Fig. 1, shows blossoms from which the petals have fallen and also small apples with their blossoms (calyces) tightly closed, so that little or no spray could be forced into them, all upon a single spur of a Duchess tree at one time. The blossoms at (a) are in just the right condition to receive and hold the poison. The two apples should have received the spray a full week earlier.

ATTACKING THE FOLIAGE.

LEAF-ROLLERS.

The fruit-tree leaf-roller (*Cacœcia argyrospila*) is a green larva with a black head and measuring about three-fourths of an inch in length when fully grown. The larvæ begin to hatch with the opening of the buds of the apple trees in the spring. They attack at

*Bull. 69, Or. Exp. Station.

once the tenderest leaves and fold them about themselves for protection. When abundant they may completely defoliate the trees. They disappear during June and do not appear again until the following spring. In the meantime the eggs may be found in little gray patches anywhere upon the bark of trunk or limbs. See Plate I., Fig. 5.

Remedies. Crush as many as possible of the egg-patches during winter and early spring. The best remedy is to spray thoroughly with one of the arsenites (4, 3, 6, 8, 5) as soon as the first leaves are out. Repeat in one week. Make a third application in another week or ten days if it seems necessary.

Protect the toads and insectiverous birds, as both feed freely upon the rollers. The blackbirds are especially destructive to them.

FALL WEB-WORM. (*Hyphantria cunea.*)

This insect is often mistaken for the next species. The webs are larger and loose or open and the caterpillars stay in them to feed.

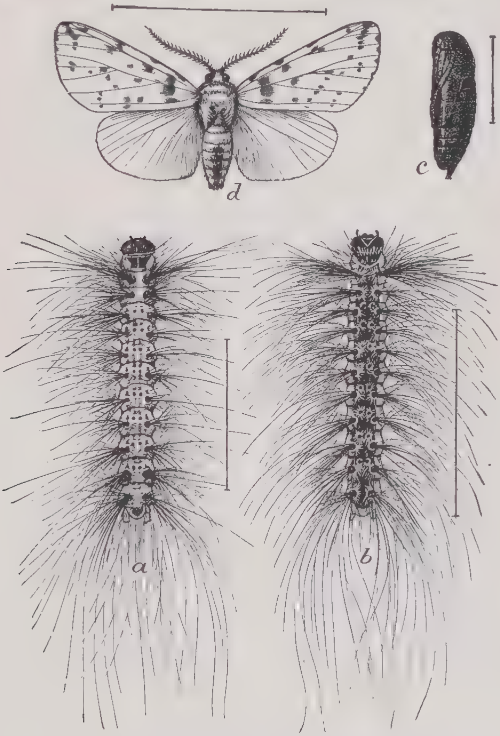

FIG. 1.—Fall Web-worm: *a* and *b*, caterpillars; *c*, chrysalis; *d*, moth. (Howard, Yearbook, U. S. Dep. of Agriculture, 1895.)

When the leaves within the tent are devoured, the web is extended so as to take in more foliage. These tents also appear later in the season than those of the following species. They will seldom be noticed before the middle of July. The adult insect is a white moth, sometimes speckled with black. See Fig. 1.

Remedies. -The same as for the following species except that it is not practical to collect the eggs which are deposited upon the leaves.

TENT CATERPILLAR. (*Clisiocampa fragilis.*)

This insect also hatches as soon as the leaf buds open, and builds small webs in the forks of the branches. A large number of caterpillars inhabit a web or tent, which is increased as necessity requires. See Plate I., Fig. 1.

Remedies.—While the foliage is off, collect the large egg-clusters which are stuck to small limbs. They are covered with a dark, spongy material and are quite readily seen, appearing as galls or swellings of the limbs. If this remedy has been neglected, spray with the arsenical mixtures (4, 3, 6, 8, 5). While the tents are small they may be cut out and burned if on small limbs. If on large limbs they may be burned out with a torch.

APPLE FLEA-BEETLE. (*Haltica* sp.)

The apple flea-beetle is a small metalic-green insect, about an eight of an inch in length, which jumps or drops from the foliage when disturbed. It is most abundant on young trees or nursery stock or sprouts.

Remedies.—Any of the arsenical mixtures (3 to 8) are effectual in destroying this insect or driving it from the foliage. It can usually be driven from the leaves by the application of dry substances, such as lime, ashes, plaster, etc. (32, 33).

BROWN MITE. (*Bryobia pratensis.*)

The brown or clover mite is extremely small and its presence is usually first detected by the faded, sickly appearance of the foliage. See Plate III., Fig. 1. The trees appear to need more water. The mites feed upon the leaves but deposit their rust-colored eggs upon trunk and limbs. When very abundant, these eggs color the bark red, which is most often noticed during winter.

Remedies. -To destroy the eggs while the trees are dormant (during winter), use lime, salt and sulfur mixture (21); kerosene emulsion (14), quadruple strength; whale-oil soap (12), quadruple strength, or crude petroleum (16). To kill the mites during summer use kerosene emulsion or whale-oil soap of ordinary strengths. It is far better to treat the eggs.

APPLE PLANT LOUSE. (*Aphis mali.*)

A green aphis curling the leaves of apple trees, most abundant late in the season, after the middle of July. See eggs on apple twig, Plate III., Fig. 4.

Remedies —For the destruction of the eggs, proceed as for the destruction of the eggs of the brown mite above. To destroy the lice, apply kerosene emulsion (14), or whale-oil soap (12), thoroughly and in a manner to bring the liquid in contact with the bodies of the lice.

SCALE INSECTS.

For the treatment of scale insects it is advisable, in each case, to write to the Experiment Station for specific directions. Specimens

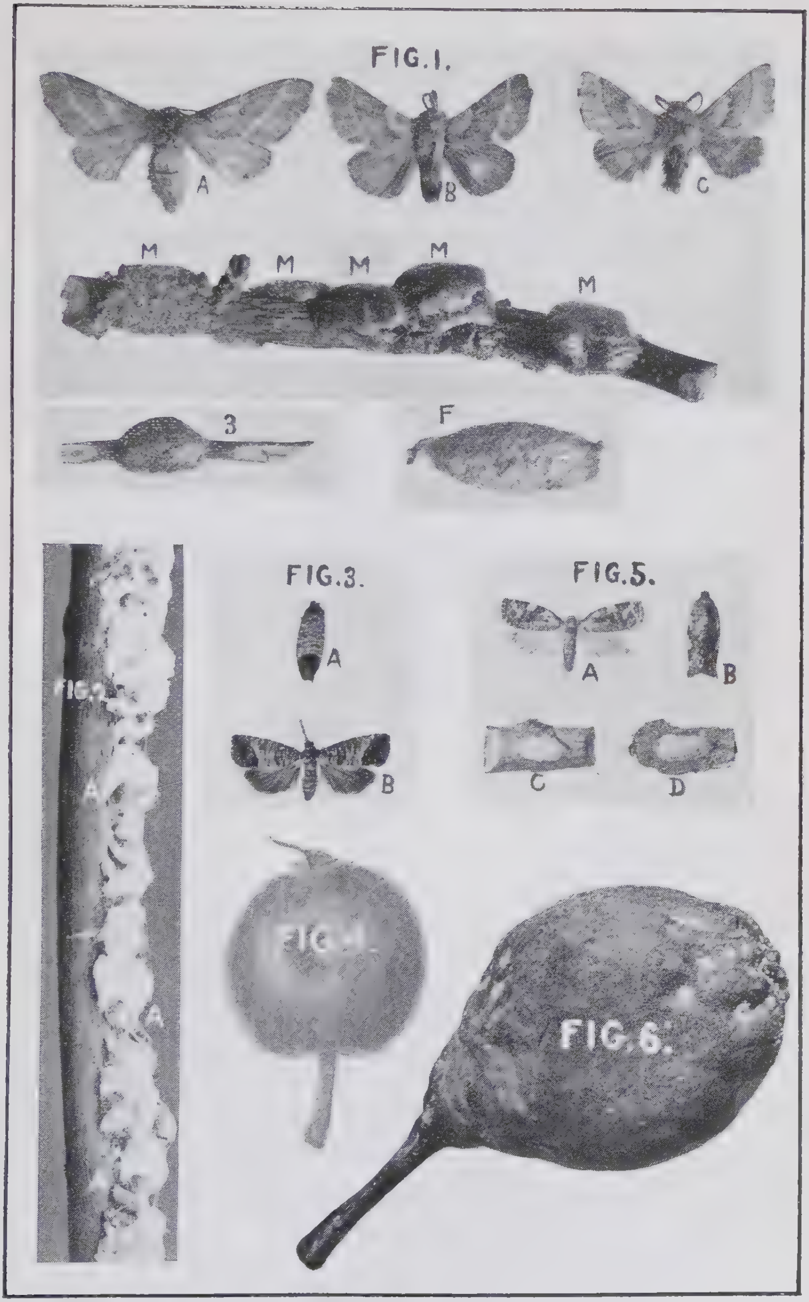

PLATE I.

FIG. 1—Western Tent-caterpillar: A, female moth; B, C, males. D, apple twig with egg masses (M). F, cocoon. 3, egg-mass of American Tent-caterpillar. Life size,

FIG. 2—Cottony Maple scale: A, scales mostly hidden by secretion. Life size.

FIG. 3—Codling moth: A, wings closed; B, open. Enlarged about ¼.

FIG. 4—Apple showing white egg of Codling Moth (under letter F). Life size.

FIG. 5—Fruit tree leaf roller: A, moth, wings open; B, closed. C, D, egg patches, hatched. All life size.

FIG. 6—Pear with Howard's Scale. The young appear as minute white specks. Life size. Figures from photos by the author.

PLATE 2.

FIG. 1—Blossoms from which the petals have fallen and still in good condition to receive the spray. Also apples with the calyces closed.

FIG. 2—Spraying scenein orchard of Mr. Bergher, Palisade, Colo. Photos by the author.

of the scale should also be sent. Otherwise, use the treatment recommended for San Jose scale. See further on.

GRASSHOPPERS.

Several species. Those that fly from tree to tree can probably be managed best by means of arsenical sprays (3 to 8), when safe to use them.

Those that crawl up the trunks into the trees and jump to the ground when disturbed, can be quite largely kept out of the trees by arsenic bran-mash (2) used freely about the border of the

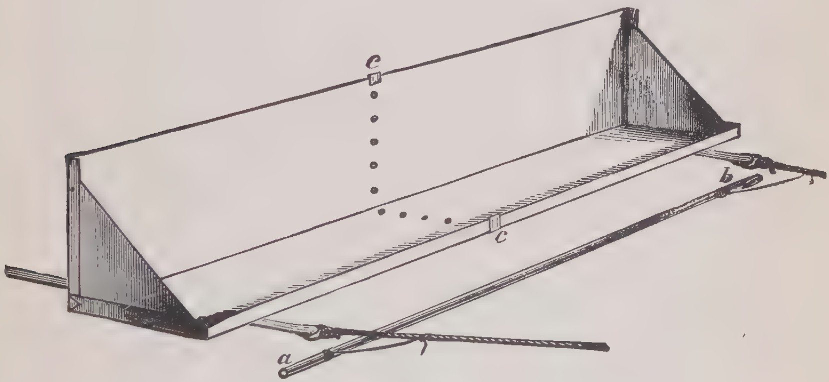

FIG. 2.—Hopper-dozer or Hopper-pan. (After Riley.)

orchard, and by sticky bands (38) of Raupenleim or printer's ink, or even cotton batting, about the trunks of the trees. If the Raupenleim or printer's ink is used, it should be spread upon a strip of cardboard which has first been wrapped about the trunk.

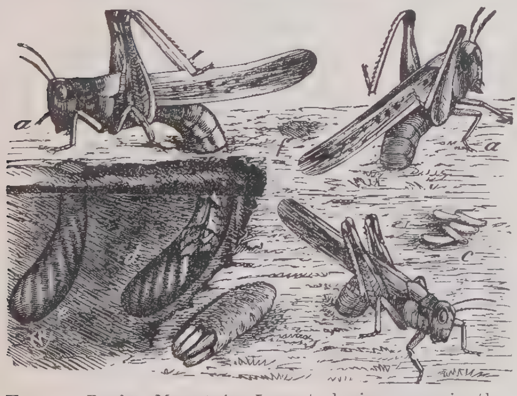

FIG. 3.—Rocky Mountain Locust, laying eggs in the ground: *a,a*, females with their abdomens in the ground; *b*, an egg-pod broken open; *c*, scattered eggs; *d*, egg-packet in the ground. (After Riley.)

Grasshoppers that injure orchards usually come from adjoining alfalfa or grass fields. In such cases the free use of the hopper-pan (37) in the alfalfa or grass field is the best remedy. One of the hopper-pans is shown at Fig. 2. At Fig. 3 female grasshoppers are shown in the act of depositing eggs in the ground.

ATTACKING TRUNK AND BRANCHES.

BORERS, FLAT-HEADED.

(*Chrysobothris femorata.*)

A whitish grub boring beneath the bark of apple and other trees and peculiar in appearance in seeming to have a greatly enlarged flat head. Fig. 4.

Remedies.—Remove with a pocket knife whenever found. Protect the south side of the trunks of the trees from the sun's heat, either by shading or white-washing during late winter and spring.

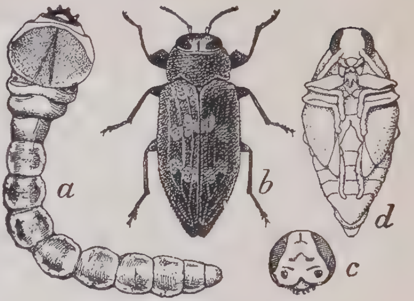

FIG. 4.—Flat-headed Apple-tree Borer: *a*, flat-headed larva; *b*, the mature beetle; *c*, head of mature beetle; *d*, pupa. All twice natural size. (Chittenden, Circular 32, U. S. Dep. of Agr., Div. of Entomology.)

APPLE TWIG-BORER. (*Amphicerus bicaudatus.*)

A cylindrical, mahogany-colored beetle, about one-third of an inch long, boring holes in twigs of apple, pear, cherry and other trees and grapevines. See Fig. 5.

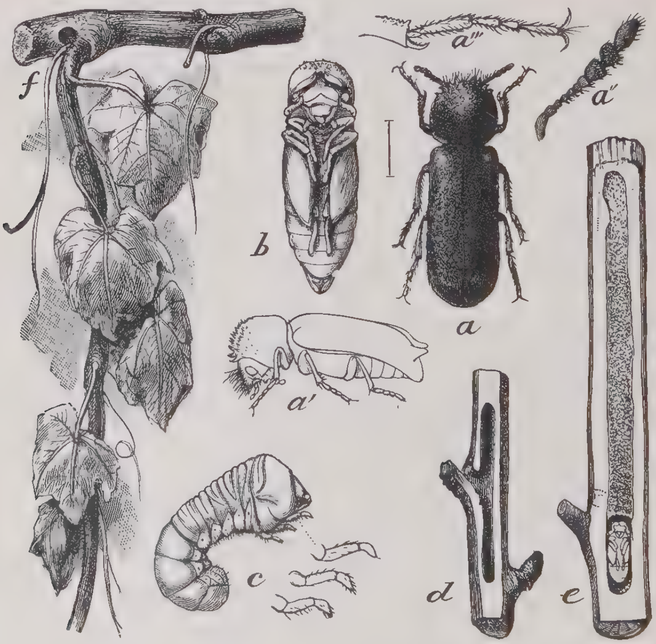

FIG. 5.—Apple Twig-borer: *a*, beetle dorsal view; *a'*, beetle side view; *b*, pupa from beneath; *c*, grub, side view; *d*, apple twig showing burrow; *e*, burrow in tamerisk with pupa at bottom; *f*, stem of grape showing burrow. All enlarged except stems showing burrows. (Marlatt, Farmer's Bulletin 70, Div. Ent., U. S. Dep. of Agr.)

Remedy.—Cut out the infested stems and destroy the borers.

BUFFALO TREE-HOPPERS. (*Ceresa* sp.)

Three-cornered, greenish to brownish insects, about a third of an inch in length. They jump when disturbed and puncture twigs of trees and stems of plants for the deposition of their eggs. From these punctures oval scars result. See Plate III., Fig. 3.

Remedies.—Infested twigs may be pruned away and burned. Probably clean culture is the best remedy. Keep down all weeds and unnecessary vegetation in and about the orchard.

SAN JOSE SCALE. (*Aspidiotus perniciosus.*)

This insect is very easily overlooked and may be present in sufficient numbers to kill trees before its presence is discovered by the orchardist. They may infest trunk, twig, fruit, or foliage. The scale is nearly circular, about one-sixteenth of an inch in diameter, dark gray in color with a rust-red spot at the center. Anyone finding such scales upon any tree should send examples at once to the Experiment Station for examination, as there are several species closely resembling each other in outward appearance. As yet this scale is unknown in Colorado orchards. See Plate I., Fig. 6, which shows a closely related species on pear.

Remedies. Spray with lime, sulfur, and salt mixture (21) while the trees are dormant. Or, spray with whale-oil soap (12) in the proportion of two pounds to a gallon of water, or with crude petroleum (16) during winter. If trees are very badly infested, it will often be best to cut and burn them.

PUTNAM'S SCALE. (*Aspidiotus ancylus.*)

Very closely resembling the preceding species. Remedies the same.

SCURVY BARK-LOUSE.

(*Chionaspis furfurus.*)

Small white scales resembling scurf or dandruff on the trunk or branches. There are two sizes, the females are larger and oval, and the males are very small and slender. See Fig. 6.

Remedies same as for the San Jose scale.

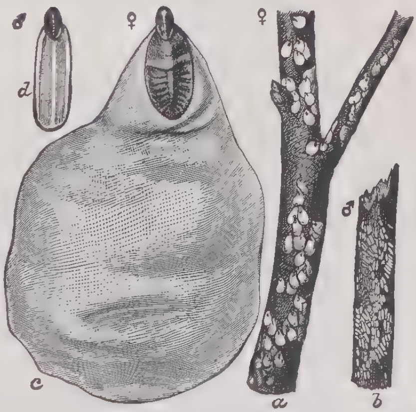

FIG. 6.—Scurvy Bark-louse: *a*, twig showing scales of female louse; *b*, twig showing scales of male louse; *c*, scale of female greatly enlarged; *d*, scale of male greatly enlarged. [Howard, Yearbook, U. S. Dep. of Agr., 1894.]

OYSTER-SHELL BARK-LOUSE. (*Mytilaspis pomorum.*)

Scales of the same color as the bark of the tree, about one-

eighth of an inch long, curved and small at one end. Very easily overlooked. See Fig. 7.

Remedies the same as for the San Jose scale.

FIG. 7.—Oyster-shell Bark-louse: *a*, female scale from below, showing eggs greatly enlarged; *b*, the same from above; *c*, female scale on twig, natural size; *d*, male scale enlarged. [Howard, Yearbook, U. S. Dep. of Agr., 1894.]

WOOLLY PLANT-LOUSE. (*Schizoneura lanigera.*)

Small dark lice more or less densely covered with a white flocculent secretion. If the lice are crushed in the hand they leave a red stain. The lice attack chiefly tender bark about wounds or on tender growing shoots.

Remedies.—Early in the season, when the white patches begin to appear on trunk and branches, paint them over with pure kerosene (16), crude petroleum, or a very strong kerosene emulsion (14), or whale-oil soap (12) mixture. If the lice become abundant late in the season, apply kerosene emulsion or whale-oil soap in ordinary strengths but with a great deal of force and a coarse spray in order to wet through the waxy secretion which covers them.

This insect also attacks the roots. See Fig. 8.

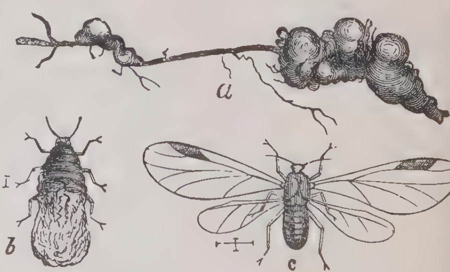

FIG. 8.—Woolly Aphis, root form: *a*, small root, showing swellings caused by the lice; *b*, wingless louse showing woolly secretion; *c*, winged louse. (After Saunders.)

ATTACKING THE ROOTS.

WOOLLY PLANT-LOUSE. (*Schizoneura lanigera.*)

This insect attacks the roots as well as the trunk and branches. It causes warty excrescences and often the destruction of the greater portion of the smaller roots (Fig. 8). The description of the louse is the same as for the trunk form mentioned above.

Remedies.—Remove the earth about the crown for a distance of about two feet, put in four to six pounds of tobacco dust (or double this amount of stems) and cover again: then irrigate. If tobacco can not be procured, use kerosene emulsion (14) or whale-oil soap (12) of the ordinary strengths in its place, pouring in a liberal quantity.

INSECTS ATTACKING THE PEAR.

Any of the insects mentioned above as attacking the apple may be found attacking the pear, except the woolly plant-louse, and the same remedies should be employed.

PEAR-TREE SLUG. (*Eriocampa cerasi.*)

FIG. 9.—Pear-tree Slug: *a*, adult fly; *b*, larva or slug with the slimy covering removed; *c*, same as preceding in natural condition; *d*, leaves showing slugs and their injuries. (Marlatt, Circular 26, Second Series, U. S. Dep. of Agr., Div. Entomology.

Slimy dark-colored larvæ with the head end much the larger, somewhat resembling snails, resting upon the upper surface of the leaves, which they skeletonize. See Fig. 9.

Remedies.—Apply white hellebore, or any of the arsenical mixtures (3-8), by dusting or by spraying. Freshly slaked lime (20) or wood ashes (32) freely dusted upon the larvæ will kill many of them.

This is an easy insect to control and should not be allowed to continue the serious injuries to the pear, plum and cherry in this State that it has been doing the past few years.

PEAR LEAF-BLISTER. (*Phytoptus pyri.*)

Small dark spots upon the leaves, sometimes very abundant and involving the greater portion of the surface. The diseased portion is thickened also and at first is green like the rest of the leaf. The leaves often fall prematurely.

Remedies.—Spray the trees while dormant with kerosene emulsion (14), treble strength; whale-oil soap (12), one pound to two gallons of water; or with lime, salt and sulfur mixture. Gather and burn as many of the fallen leaves as possible.

HOWARD'S SCALE. (*Aspidiotus howardi.*)

Was found attacking pears badly in an orchard near Delta, Colo., last summer. This is a close relative of the pernicious, or San Jose scale, but, so far, has been known only upon plum and pear. Pears, or any fruit affected with scales, should be reported promptly to the Experiment Station. See Plate I., Fig. 6.

Remedies.—The same as for San Jose scale mentioned under apple insects.

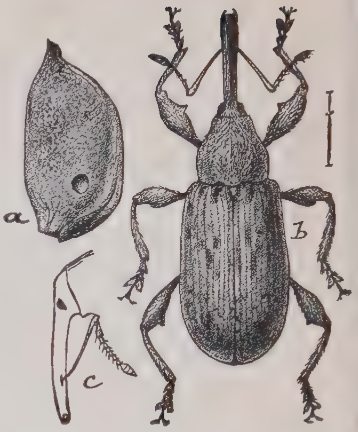

FIG. 10.—Plum Gouger: *a*, plum pit showing hole for exit of gouger; *b*, gouger; *c*, side view of head of gouger showing beak and antenna. (Riley & Howard, Insect Life, Vol. II., U. S. Dep. of Agr., Div. of Entomology.

INSECTS INJURIOUS TO THE PLUM.

ATTACKING THE FRUIT.

PLUM GOUGER. (*Coccotorus prunicida.*)

A small but rather robust snout-beetle about a quarter of an inch in length; color a leaden gray with head and thorax ochreous yellow; wing covers smooth without prominent humps on them. The beetle eats pin-holes in the growing plums in which it lays its eggs. The larva or grub eats into the pit and flesh on the kernel and later eats a hole out through both pit and flesh of plum just before the plum matures (Fig. 10). Attacks the red, or Americana varieties only. Only insect in Colorado injuring the fruit of the plum to any extent.

Remedies. — Jar the trees early every morning, or in the evening, from the time the blossoms are out till very few beetles can be obtained, catching them on a sheet spread beneath. It only takes a very few beetles to do a great amount of harm, as I have found by actual count that a single female may lay as many as 450 eggs.* Gathering and destroying all stung plums during the early part of July would nearly exterminate this insect. Spraying with an arsenical poison (4, 3, 6, 7, 5, 8) once, a few days before the trees blossom, and once or twice after, will give considerable protection. Use the poisons in two-thirds ordinary, or standard strengths. Arsenate of lead (5) is probably the safest to use on the foliage of the plum.

PLUM CURCULIO. (*Conotrachelus nenuphar.*)

This beetle is often confused with the preceding. As yet it has not been reported in Colorado. It is liable any year to appear in

*Insect Life, III., p. 227.

our orchards and all should be on the look out for it so as to do all possible to stamp it out or prevent its rapid spread. It is to the European varieties of plums what the codling moth is to the apples, only worse. The beetle is brown to blackish in color, is about one-fifth of an inch long and has two prominent humps and numerous smaller ones upon its wing covers. The beetle makes a crescent-shaped cut in the flesh of the fruit where an egg is deposited and the grub does not enter the pit but feeds on the flesh outside of it, causing the fruit to fall.

Remedies.—Jarring and spraying as in case of the preceding species.

Should anyone find what he thinks to be the work of this insect in his orchard, it is hoped he will notify the Experiment Station at once.

ATTACKING THE FOLIAGE.

FRUIT-TREE LEAF-ROLLER. (*Cacœcia argyrospila*)

See under apple insects. Use the poisons only two-thirds as strong on the plum as on the apple. Arsenate of lead is probably least likely to injure the foliage.

SLUGS.

Skeletonizing the upper surface of the leaves. See pear-tree slug. Use the same remedies.

BROWN MITE.

See under apple insects. Remedies the same.

PLANT LICE.

Two or three species attack the foliage of the plum badly in Colorado. Remedies the same as for apple plant-louse.

Other insects attacking apple foliage may be found on plum, where they are destroyed by the same treatment in either case.

ATTACKING TRUNK AND BRANCHES.

THE PEACH BORER. (*Sannina exitiosa.*)

This insect often attacks the plum. For its treatment see peach enemies.

FLAT-HEADED BORER.

See under apple enemies.

SCALE INSECTS.

See under apple enemies. When scales are found it will be well to send specimens to the Experiment Station for identification and advice. Howard's scale and Putnam's scale both occur on plum in the State. They have been injuriously abundant in a few isolated cases only.

INSECTS INJURIOUS TO THE CHERRY.

The insects attacking the cherry in Colorado are the Fruit-tree Leaf-roller, Tent Caterpillar, Fall Web-worm, Brown Mite, Plant Lice, Scale Insects, Grasshoppers, Flat-headed Borer, Twig Borer, Buffalo Tree-hoppers and Pear Slug mentioned above.

INSECTS INJURIOUS TO THE PEACH.

PEACH TWIG-BORER. (*Anarsia lineatella.*)

This is the worst peach enemy in Colorado at the present time. As soon as the buds begin to open in the spring, a small brownish larva with a black head eats into the buds and destroys them. When the new shoots start, the borer eats into them causing them to wilt and die. Many of the second brood of this borer eat into the peaches, causing a gummy exhudation and ruining them for market. The larvæ that appear in the spring spent their winter in little excavations which they made in the fall in the bark of the trees. See Figs. 11 and 12.

Remedies.—Early in the spring, just before the buds open, spray the trees with lime, salt and sulfur wash (21), whale-oil soap (12) in the proportion of a pound to two gallons of water; fish-oil soap (13) diluted once with water, or kerosene, will doubtless do the work nearly or quite as well as the lime, sulfur and salt. Many of the larvæ may be caught under bandages (36) used as for the codling moth.

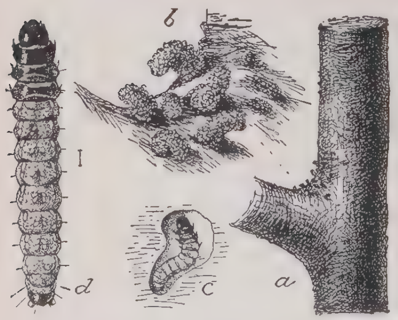

FIG. 11.—Peach Twig-borer: *a*, twig of peach showing little masses of chewed bark above the larval burrows; *b*, the same enlarged; *c*, larva in winter burrow, enlarged; *d*, hibernating larva greatly enlarged. (Marlatt, Bulletin 10, N. S., U. S. Dep. of Agr., Div. of Entomology).

FIG. 12.—Peach Twig and Borer: *a*, young shoot wilting from attack of borer; *b*, adult larva enlarged; *c*, chrysalis enlarged; *d*, tail end of chrysalis showing hooks. (Marlatt, Bulletin 10, N. S., U. S. Dep. of Agr., Div. of Entomology.)

THE PEACH BORER.

A yellowish white borer attaining the length of about one inch, boring beneath the bark of the lower trunk and larger roots. See Plate IV.

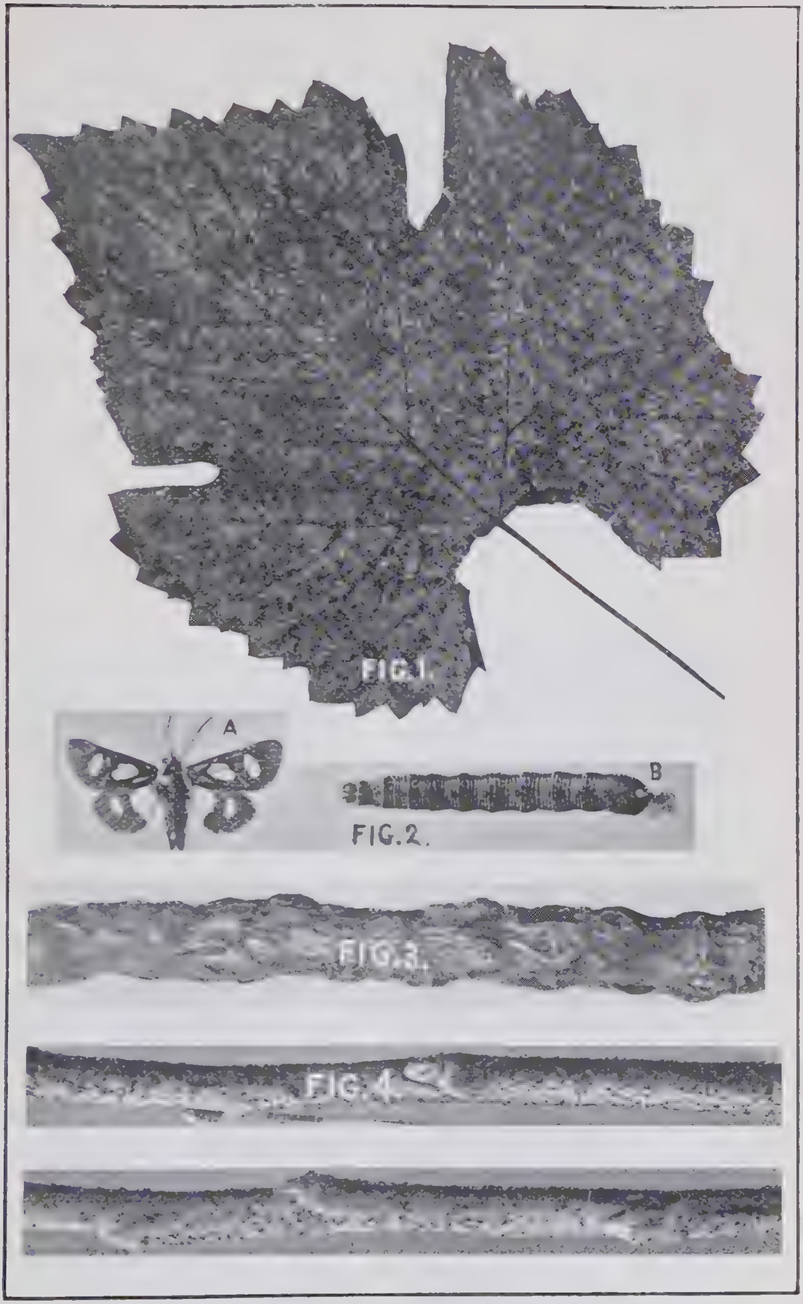

PLATE 3.

FIG. 1—Grape leaf showing bleached appearance due to grape-leaf hopper (*Typhlocyba comes*).

FIG. 2—Eight-spotted Forester (*Alypia 8-maculata*): A, moth; B, larva. Nearly life size.

FIG. 3—Apple twigs injured by Buffalo Tree-hopper (*Ceresa sp.*) Life size. Photos by author

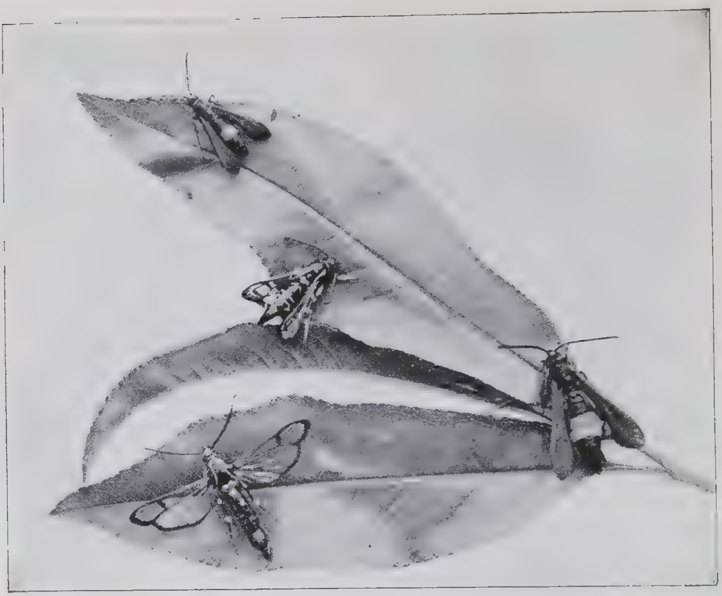

FIG. 1—Moths of Peach Borer.

FIG. 2—Peach tree bandaged with paper.

FIG. 3—Peach tree with wire screen. All after Slingerland, (Bull. 176, Cornell Expt. Station.)

PLATE 4.

Remedies.—Carefully inspect the trees every fall and spring, remove some of the earth next the crown, and search for and remove the borers with the aid of a pocket knife. Their presence is usually indicated by the exhudation of a gummy material upon the bark. Shields of stout paper or wire screen placed about the trunks and left there from the 1st of May till the 10th of July will serve as a means of protection from egg-laying. The paper screen is the better. (See Plate IV., Figs. 2 and 3.

PLANT LICE.

The plant lice that attack the foliage of the peach may be treated in the same way as the apple plant-louse mentioned above. The black peach aphis, which does its chief injury to the roots, should be handled in the same manner as the woolly louse of the apple.

INSECTS INJURIOUS TO THE GRAPE.

THE ACHEMON SPHINX. (*Philampelus achemon.*)

Hairless caterpillars devouring the leaves. When small, the caterpillar have each a long dorsal spine on the last segment of the body. When nearly grown, the spine is represented by a shining black spot. These larvæ resemble the large tomato "worm."

Remedies.—Any of the arsenical poisons may be used as recommended for apple leaf-rollers. Pyrethrum (24) may also be used as a powder or spray, but to kill it must come in contact with the caterpillars. Hand picking is the best remedy in a small vineyard.

This insect is also bad on Virginia creeper.

THE EIGHT-SPOTTED FORESTER. (*Alypia octomaculata.*)

A dark colored caterpillar, about one and one-half inches long when fully grown. A close examination will reveal numerous small black and white cross lines and a few red ones to each body segment. See Plate III., Fig. 2.

Remedies.—The same as for the preceding species.

This insect also infests the Virginia creeper.

BORER.

See apple twig-borer, which also attacks the grape.

TREE CRICKETS. [*Œcanthus* sp.]

The female cricket punctures stems of grape and other plants and in each puncture deposits a long cylindrical egg. The punctures are usually in rows lengthwise of the stem and look like needle thrusts.

Remedies.—Cut out badly infested stems. Keep the vineyard clean of all weeds.

COTTONY SCALE. [*Pulvinaria innumerabilis.*]

This scale, commonly found infesting soft maple, sometimes attacks grapevines. See Plate I., Fig. 2.

Remedies.—When the little lice first hatch from the scales, about the last of June, the ordinary sprays of kerosene emulsion (14) or whale-oil soap (12) will

destroy them. If the spraying is delayed till a heavy scale has formed over the lice, stronger applications will be required.

GRAPE FLEA-BEETLE. [*Graptodera chalybæa.*]

A small steel-blue beetle appearing early in the spring and again in midsummer and feeding upon the foliage. The beetles deposit eggs which soon hatch into small dark-colored larvæ which also eat holes in the leaves.

Remedies.—Arsenical poisons (3-8) sprayed or dusted upon the foliage. If unsafe to use poisons, dust freely with Pyrethrum (24).

GRAPE LEAF-HOPPERS. [*Typhlocyba* sp.]

Small jumping and flying insects, often called "grape thrips." The insects often fly out from the vine in great numbers when the latter is jarred and return quickly to the under side of the leaves. As a result of the punctures and the extraction of the sap, the leaves lose their dark green color and at first are minutely specked and freckled with white, as shown at Plate III., Fig. I. Later the leaves shrivel and die. The red spiders, brown mites and thrips cause a similar appearance of the foliage they attack.

Remedies.—Spray forcibly with kerosene emulsion (14), kerosene and water (16), or whale-oil soap (12) very early in the morning while the insects are dormant and drop readily from the leaves. Burn dry leaves, dead grass and other rubbish in the vicinity of the vineyard during winter or early spring, on a cold day.

GRASSHOPPERS.

Remedies.—Use arsenical spray (3-8) where safe. If not safe to spray, use the arsenic-bran mash (2) freely about the borders of the vineyard and about the vines. Make free use of hopper-pans (37) in adjoining fields to reduce the number of hoppers before they reach the vineyard. Plow or thoroughly harrow the ditch banks and the borders of the field late in the fall to destroy as many of the eggs as possible.

INSECTS INJURIOUS TO THE CURRANT.

IMPORTED CURRANT-BORER. [*Sesia tipuliformis.*]

Yellowish white larvæ burrowing in stems, giving rise to wasp-like moths in June. The moths closely resemble those of the peach borer, shown at Plate IV., Fig. 1.

Remedies.—Cut out the infested stems and burn them during winter or early spring. Also keep the old wood well trimmed out of the bushes.

CURRANT SAW-FLY. [*Pristiphora grossulariæ.*]

A green larva, about half an inch long when fully grown, feeding upon the leaves of currant and gooseberry bushes. Appearing late in June and again about the last of August. The adult insect is a black four-winged fly about the size of a house-fly. The eggs are deposited, one in a place, under the epidermis of the leaves.

Remedies.—The best remedy for this pest is white hellebore (9) dusted ightly over the foliage in the evening. If this is carefully done, nearly every

larva can be found dead under the bushes next morning. Arsenical sprays (3-8) may be used either dry or in water, as for other leaf eating insects. These poisons should not be used before the currants are picked. Pyrethrum (24) may be safely used at any time.

INSECTS INJURIOUS TO THE STRAWBERRY.

STRAWBERRY LEAF-ROLLER. [*Phoxopteris fragariæ.*]

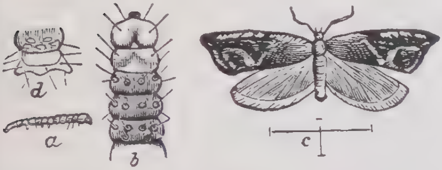

FIG. 13.—Strawberry Leaf-roller: *a*, larva, natural size; *b*, head end of larva enlarged; c, moth about twice natural size; *d*, tail end of larva enlarged. (After Saunders.)

Small brownish or greenish larvæ attaining a length of nearly half an inch and having the habit of folding the leaves of the strawberry. In these folds the larva lives and feeds and finally changes to a small rust-colored moth with white markings on the wings. See Figs. 13, 14.

Remedies. — When the fruit has been gathered, scatter straw over the vines and burn it. Arsenical sprays (3-8) may be used, but the worms are so protected in the folded leaves that it is difficult to get a poisonous dose to them. The vines will put up a good growth of tops after the burning, if it is not done too late.

STRAWBERRY CROWN BORER

[*Tyloderma fragariæ.*]

A small yellowish white grub boring into the crown of the plant during summer.

Remedies. — Burning as for the preceding species will destroy a large proportion of the borers. Do not allow the plants to become very old, but plow frequently as soon as the berries are picked and start a new bed at some distance from the old one. Poisons are of doubtful value.

FIG. 14.—Strawberry leaves showing their appearance after being folded by the roller. (After Weed.)

PART II.

INSECTICIDES.

THEIR PREPARATION AND USE.

In order to be able to apply insecticides intelligently and with success, it is important to understand something of the habits of the particular insects to be destroyed and also of the nature of the remedies to be used. Many insects, like grasshoppers and the potato beetle, devour the surface tissue of plants, while others, like plant-lice, squash-bugs, and scale insects, insert sharp tubular beaks into the tissues of plants and suck the sap from beneath the surface. Insects of the first class may nearly always be destroyed by means of food-poisons, such as arsenic, Paris green, hellebore, etc., while those of the latter class are unaffected by food-poisons and have to be killed by substances that come in contact with the surface of their bodies, or in some other manner. It is not necessary to be a skilled entomologist in order to determine which class of insects are doing injury to the plants in question. If the leaves are ragged or eaten full of holes, it is practically certain that the injury is being done by an insect with biting mouth-parts. If the leaves simply wilt and dry up without having the tissue eaten away, the insect doing the injury is of the second type mentioned. The most common remedies for this class of insects are kerosene emulsion, whale-oil soap, crude petroleum, and lime-sulfur and salt washes.

In many cases it is impossible to get an insecticide upon the insect that it is desired to kill, or upon its food, and then other means have to be used to prevent the injuries. Borers, underground feeders upon roots, and weevil living in seeds, are examples of such insects.

In the pages that follow I shall not attempt to treat of all the methods used to destroy insects or avoid their injuries, but the more important ones only.

SUBSTANCES THAT KILL BY BEING EATEN.

Nearly all the food-poisons have for their active principle arsenious acid, or white arsenic ($AS_2 O_3$). White hellebore and borax are about the only exceptions.

1. WHITE ARSENIC.

While this is the cheapest of the arsenical poisons, it is used but little, except for the purpose of making arsenical compounds with other substances, such as lime, copper and lead. Because some States have passed laws requiring a high percentage of arsenic in Paris green, arsenic has been used as an adulterant of Paris green and thereby working an injury to the purchaser if not a benefit to the manufacturer of it, because arsenic is much cheaper than Paris green, and when it is mixed with the latter it greatly increases its liability to burn foliage. The reason that white arsenic burns foliage badly is it dissolves in water and, when in solution, it penetrates the leaves and kills the living tissue. Arsenical mixtures must *never be in solution, but only in suspension*, in the water that is used to distribute them upon foliage.

2. ARSENIC BRAN-MASH.

Prepared by mixing one pound of arsenic and six to ten pounds of bran together, with just water enough to thoroughly moisten the mass. Some prefer to add a pound of sugar to the above in order to cause the particles of bran to adhere to each other, so that it may be distributed in little balls pressed together with the hands or with a paddle. This poisoned bran is used for the destruction of grasshoppers in orchards and vineyards where it is not possible to use a hopper-pan.

3. PARIS GREEN.

This poison in a pure state is said to be composed of three substances—arsenious acid, acetic acid, and copper oxide—united in a chemical combination. The percentage of arsenic may vary considerably, as these substances do not always combine in exactly the same proportions. The range is nearly always between 55 and 60 per cent arsenic, with an average of about 58 per cent. *Mr. J. K. Haywood, one of the chemists in the Department of Agriculture at Washington, D. C., says that the chemical composition of Paris green should be:

	Per cent.
Arsenious acid	58.65
Copper oxide	31.29
Acetic acid	10.06

Pure Paris green is one of the very best of the arsenical compounds for the destruction of insects, and the reports of many analyses in different States do not indicate that this poison is often found greatly adulterated upon the market. If adulteration is suspected, or if the poison is being purchased in any considerable quantity, it is advisable to test its purity in some way. Pure Paris

*Farmer's Bull. No. 146, U. S. Dept. of Agr.

green is entirely soluble in ammonia, giving a clear blue liquid. If any particles can be seen floating through the liquid or settling to the bottom, the article is not pure. If the ammonia dissolves all, there can be little doubt that it is pure. This is a test that anyone can make. The particles of Paris green are entirely bright green in color and globular in form, and the presence of an adulterant can be most easily detected under a microscope of moderate power. Prof. Woodworth of the University of California explains another method by which impurities can usually be detected in Paris green. It is by placing a small amount of the poison on a clean piece of glass and then slanting the glass and jarring it so as to cause the powder to slide to the lower side. If this is done carefully the adulterants, which are not green in color, will fall behind and can be detected with the unaided eye.

Where there are several persons in the same neighborhood wanting this poison, it is best for all to order together and then send a sample to a chemist for analysis. If a good number unite in this way the Station chemist, most likely, would be willing to make the test free.

Application of Paris Green to Plants.—The arsenical mixtures are usually applied in a watery spray, and the most common strength is:

Paris green	1 pound
Water	160 gallons
Lump lime (freshly slaked)	2 pounds

On very sensitive foliage, like that of the peach, apricot, nectarine and bean, it would be safer to use 200 gallons of water to a pound of the poison. A pound to 100 gallons is quite safe for applications upon apple, cherry, cabbage, beets, potatoes, and most other trees and plants in the dry atmosphere of Colorado. The poison always should be placed in a small quantity of water first and thoroughly stirred in and then poured into the full amount of water to be used.

The chief objection to the use of Paris green as an insecticide is its high specific gravity, which causes it to settle rapidly in water. Pumps used to apply this poison always should have some means of keeping the water well stirred.

Dry applications may be made in various ways. Sometimes the poison is used pure, in which case the lightest possible dusting is made over the plants. It is usually better to dilute the poison with about twenty times its own weight of flour, plaster or lime, when a more liberal dusting may be made. This method is more economical of the poison and enables one better to tell when all parts of the plant have been treated. A good proportion is:

Paris green	1 pound
Common flour	20 pounds

The advantages of flour over lime or plaster are, it helps better to stick the poison to the leaves and is not distasteful to insects. Particles of poison imbedded in a mass of plaster or lime would probably be avoided by most insects. Filling the blossom ends of apples with lime mixed with poison will drive the worms to eat their way into the apple, where they will probably escape the poison entirely.

The methods of applying dry poisons are chiefly two. If low plants, like cabbages and tomatoes, are to be treated, and the area to be covered is not too great, a very satisfactory method is to make a small sack—about ten inches long by five inches in diameter—of strong cheesecloth or other light muslin, fill half full with the mixture of poison and flour and then shake or jolt the sack over the plants.

Where large areas are to be treated, or where it is necessary to make the application to trees or high bushes, some kind of dust gun or bellows is an advantage. Powder guns of different kinds are upon the market and some of them are being extensively advertised at this time. These instruments have an important place to fill, but I doubt very much if they can take the place of the watery spray for large trees, and particularly for the application of poisons for the destruction of the codling moth.

4. SCHEELE'S GREEN (GREEN ARSENOID).

Scheele's green, also sold as "green arsenoid," differs very little from Paris green in chemical composition, except in lacking the acetic acid. It is considered as effectual as an insect destroyer, and has a great advantage over Paris green in being much more finely divided, so that it remains in suspension in water for a much longer time. It is also cheaper in price. Dr. Marlatt, of the Division of Entomology, says it should replace Paris green as an insecticide.

Apply either wet or dry, as recommended for Paris green.

5. ARSENATE OF LEAD.

This compound contains only about 25 per cent. of arsenic acid, but has some advantages over the other arsenical compounds. It is so completely insoluble in water that it may be used in almost any strength without injuring foliage and consequently is least likely to injure plants that are most sensitive to arsenical poisons. When suspended in water this poison takes the form of a flocculent precipitate that remains suspended a long time without settling, and consequently can be more evenly distributed than most arsenical mixtures. Its third point of superiority is in its adhesive qualities when applied to foliage. Applications made to foliage in the latter part of May at this Station could plainly be seen upon the leaves the first of September. The disadvantage of the poison is in its not being as destructive to the insects that eat it as are the other

arsenites, consequently it is necessary to use it in stronger mixtures.

To prepare arsenate of lead, dissolve in water arsenate of soda and acetate of lead (white sugar of lead) in the proportion of three pounds of the former to seven pounds of the latter. Then use not less than two or three pounds of the combined chemicals to each hundred gallons of water. Three or four times this strength will do no harm to foliage.

6. ARSENITE OF LIME.

White arsenic and lime may be made to combine, forming an arsenite of lime that is practically insoluble in water. The poison may be prepared in either of two ways. What is known as the Kedzie formula is as follows:

> "Boil two pounds of white arsenic and eight pounds of sal-soda for fifteen minutes in two gallons of water. Put into a jug and label '*poison*,' and lock it up. When ready to spray, slake two pounds of lime and stir it into forty gallons of water, adding a pint of the mixture from the jug."

The other method is to boil together arsenic, lime and water for a full half hour in the following proportions:

White arsenic	1 pound
Lump lime	2 pounds
Water	3 gallons

Then dilute to 200 gallons of water before applying to foliage.

These preparations have become very popular in the past two years and deservedly so. White arsenic is cheap and consequently is in very little danger of adulteration, so that one is almost certain of the strength of his mixture when using this poison. Care must be taken, however, to *use fresh, unslaked lime of good quality.*

Before being diluted for use, the mixture should be passed through a coarse cloth or sieve, to take out the lumps that would otherwise clog the spraying nozzle.

7. LONDON PURPLE.

London purple is a by-product in the manufacture of aniline dyes and has for its active principle arsenite of lime. It also contains some free arsenic, lime, coloring matter and other impurities. The amount of arsenic present is subject to considerable variation, but will usually range between 40 and 55 per cent. As there is often considerable soluble arsenic present, it is always best to use a pound or two of freshly slaked lime with every pound of the poison if used in water.

This poison is finely divided and remains in suspension in water much longer than does Paris green, and it usually sells at about two-thirds the price of that poison. It seems to be going into disfavor because of its variable composition and the danger of its

burning foliage. It is also considered somewhat less effectual in killing insects than is Paris green or Scheele's green. It should compare favorably, however, with the prepared arsenite of lime in its power to kill insects, and there is little danger that it will be adulterated, as it is a waste product.

Apply either wet or dry in the manner and in the same proportions as are previously recommended for Paris green, being sure to add a pound or two of freshly slaked lime for each pound of poison if used as a spray.

8. BORDEAUX MIXTURE AND THE ARSENITES.

Bordeaux mixture is a fungicide and is the substance most often used for the destruction of fungi that attack the surface of plants. It has been found to be of value for use against flea-beetles, and the writer also demonstrated its value a number of years ago as a medium in which to spray Paris green or London purple. These poisons can be used very strong in this mixture without injury to foliage and they do not in the least lessen its effect as a fungicide. Such a mixture will destroy both insects and fungi with one application.

Bordeaux mixture may be prepared as follows: Take of

Copper sulfate	4 pounds
Quicklime	4 pounds
Water	45 gallons

Dissolve the copper sulfate in a gallon of hot water, slake the lime in another gallon of water, and then add the milk of lime slowly to the copper sulfate solution while the latter is being constantly stirred. Then add 43 gallons of water.

If insects are to be killed at the same time, add to the above quantity of Bordeaux mixture one-third pound of London purple, Paris green or Scheele's green.

9. WHITE HELLEBORE.

Hellebore, as obtained from drug stores, is a light, yellowish-brown powder. It is a vegetable poison and is obtained by pulverizing the roots of a European plant, *Veratrum album.* It is not as poisonous as the arsenites and consequently is not as effective in the destruction of most insects, but it has its special uses. Slugs, which are the young of saw-flies, are particularly susceptible to its effects. The poisonous property is an alkaloid and it loses its virtue after being exposed to the air for a few days. For this reason it can not be used where it is likely to remain long before being eaten, and it must be kept in tight receptacles and must not be kept too long before using. It is often useful for the destruction of insects upon plants containing fruit that will soon be used for food.

Dry applications are easily made upon low plants by making a

small cheesecloth sack, through which the dust may be sifted lightly over the foliage. The best time to apply is in the evening.

In the wet way use

White hellebore	1 ounce
Water	3 gallons

Apply as a spray in the evening.

10. BORAX.

Used chiefly for the destruction of cockroaches. Spread the powdered borax upon bread, sweet potato or banana peelings, or mix with sweetened chocolate, and place the bait where the cockroaches can get at it.

SUBSTANCES THAT KILL BY EXTERNAL CONTACT.

Substances in this group are chiefly used against insects that take liquid food from beneath the surface of the plant by means of a tubular rostrum or beak, but they may be used against many other soft-bodied insects with success. Insects having a hard outer crust to their bodies resist these substances and are not easily killed by them. If insects are covered with a powdery or cottony material, the insecticide will have to be applied with considerable force to cause it to penetrate to the body. Applications must always be thorough, because only those insects will be killed that have the substances thrown upon them.

11. SOAP.

The ordinary soft soaps and laundry soaps have long been used for the purpose of killing vermin on plants and animals, and they have considerable insecticidal value, particularly for the destruction of very tender insects, like plant lice. There are two kinds of soap that are specially useful for the destruction of insects, and these are whale-oil soap and fish-oil soap.

12. WHALE-OIL SOAP.

For ordinary plant lice one pound of the soap to eight or ten gallons of water is sufficient if the application is thorough. Double this strength will not injure most plants and is often required to destroy more resistent insects. For scale lice, like the San Jose scale for example, it is used as strong as a pound, or even two pounds, to a gallon of water. These strongest applications can only be used in the winter or early spring when the trees are dormant. The soap is more effectual if applied when quite hot.

13. FISH-OIL SOAP.

Lodeman in his "Spraying of Plants" gives the following formula for the preparation of fish-oil soap:

Potash lye	1 pound
Fish oil	3 pints
Soft water	3 gallons

Dissolve the lye in boiling water and then add the oil and boil for two hours longer. Before using dissolve a pound of this soap in from six to ten gallons of water. Use for the same purposes as whale-oil soap, and in the same strengths.

14. KEROSENE EMULSION.

This preparation is probably the best general purpose insecticide for the destruction of insects by external contact. The materials composing it are always at hand and it is not difficult to prepare after one has had a little experience. Soft water should be used, if possible. If very hard water is used it may be necessary to "break" it first by adding washing soda or potash lye.

To make the emulsion use the ingredients in the following proportions:

Soap	1 pound
Kerosene	2 gallons
Water	27 gallons

Prepare by dissolving the soap in a gallon of water, then, while the soapy water is boiling hot, remove from the fire and immediately add two gallons of kerosene and agitate briskly for a few minutes. If a large amount is being made use a force pump and forcibly pump the mixture back into the receptacle that contains it until all is a frothy, creamy mass. If such a mixture is not obtained in a very few minutes, put the whole over the fire again until it boils and then repeat the pumping, and the emulsion will almost surely form. When put back for reheating *watch every moment to see that it does not boil over and take fire.* This work should be done out of doors. After the emulsion is made, add the remaining 27 gallons of water and all is ready for use.

Small quantities may be emulsified with a rotary egg-beater.

Whale-oil soap, or any cheap laundry soap, may be used.

Clean dishes and clean water should be used. Every particle of dirt in the emulsion serves as a center of attraction about which the oil droplets will collect and then rise to the top to form a film of oil on the surface.

The strength above given is suitable for most insects. Most plant lice may be killed with an emulsion of half the above strength.

15. KEROSENE-MILK EMULSION.

Kerosene will emulsify with milk, also, and when small quantities are wanted it is often less trouble to use the milk than to prepare the soapy water. The proportions are:

Milk (sour)	1 gallon
Kerosene	2 gallons

Dilute with water as in the preceding formula. If sweet milk is used add a little vinegar. Otherwise it may be impossible to form a stable emulsion.

16. KEROSENE AND CRUDE PETROLEUM.

These oils are used pure, and also diluted with water, for the destruction of scale and other insects. Experiments in the Eastern States seem to indicate that the safest time to apply is early in the spring, just before the buds swell, and on a bright, windy day when the oil will evaporate rapidly. It seems that when applied in moderation, in the proporiion of 40 parts of the oil to 60 of water, these substances will seldom injure apple, cherry or pear trees, but can hardly be applied to tenderer trees, such as peach and plum, without farther dilution.

When diluted with water in the form of a spray they may be used upon foliage of most plants, without injury, in the proportion of one of the oil to five or six of water. Most plant lice are killed in mixtures as weak as one to fifteen or twenty.

Pumps are now made for the purpose of mixing the oil and water in the form of a spray, and so doing away with the need of preparing an emulsion. The one who has the insecticides to apply must decide whether or not he will go to the extra trouble of making the emulsion or whether he will go to the extra expense of purchasing a special and somewhat more costly pump.

17. GASOLINE.

This oil is also destructive to insect life. Its chief use is for the destruction of bed-bugs. It is applied pure by means of an oil-can or hand atomizer. To be effectual the bugs must be thoroughly treated with it. As it is inflammable, care must be taken not to bring fire near until the apartments where it is used are well aired.

18. TURPENTINE.

Turpentine is used for the same purposes as gasoline and the same precaution applies.

19. LYE AND WASHING SODA.

These substances are in considerable popular favor for the destruction of insects, but the writer's experience with them has not been encouraging. In the proportion of a pound to three gallons of water they may be used upon the trunks of trees and will kill soft-bodied insects that might be wet by them. To be used upon foliage they should be diluted to a pound to forty gallons of water, and in this strength they will only destroy the tenderest of insects. Kerosene emulsion or whale-oil soap are much more effectual insecticides.

20. LIME.

Lime, either wet or dry, may be used freely upon foliage without fear of injury. It is of very little value as an insecticide. When freshly slaked and freely dusted upon the slugs that infest pear, cherry and plum trees it is said to be very effectual in destroying them. Experiments at this Station have not succeeded very well in killing slugs this way. As a coating upon the bodies of fruit trees it undoubtedly does much to prevent sun-scald late in winter and early in spring. The addition of a liberal amount of skim-milk or salt, or both, to the preparation will greatly increase its adhesive qualities. The following formula is printed in the 1899 report of the Canada Experimental Farm:

Skim-milk	6 gallons
Water	30 gallons
Lime	60 pounds
Salt	10 pounds

21. LIME, SALT AND SULFUR WASH.

This wash, when properly made, is one of the most effectual applications for the destruction of scale insects and eggs of the brown mite, particularly in dry climates, like that of Colorado. It should be used only in the winter or spring, while the trees are dormant. The ingredients are used in the following proportions:

Lump lime	30 pounds
Sulfur	20 pounds
Salt	15 pounds
Water	60 gallons

Put all together in a barrel or other receptacle and boil for four or five hours. If a wooden receptacle is used, steam boil. Strain through a coarse cloth to take out coarse lumps, and apply as a spray while hot.

22. RESIN SOAP (SUMMER WASH).

A resin soap for summer use may be prepared in the following proportions:

Resin	2 pounds
Caustic soda	1 pound
Tallow	1 pound

Dissolve the soda in one and one-half gallons of water; then add the resin and tallow and dissolve them also by applying a moderate degree of heat, adding water enough to make three gallons. Before using, dilute one part of the soap with sixteen parts of water.

Used for the same insects as are whale-oil soap and kerosene emulsion.

23. RESIN SOAP (WINTER WASH).

*Resin	30	pounds
Caustic Soda (70 per cent.)	9	pounds
Fish-oil	4½	pints
Water	100	gallons

Place the first three ingredients in an iron kettle and cover with five or six inches of water. Boil for an hour or two until the liquid has a dark brown color, after which the remainder of the water may be added.

Other formulæ for the preparation of resin soaps have been given, but as they are not much used, I will not take space to give them here.

24. PYRETHRUM, OR BUHACH.

This substance is a vegetable powder and is obtained by pulverizing the dried blossoms of plants of the genus Pyrethrum. It may be obtained at almost any drug store, and is peculiar in its power to kill insects while it is not poisonous to the higher animals. It may be used either wet or dry. If applied in water, use in the proportion of:

Pyrethrum	1 ounce
Water	3 gallons

If applied dry, use pure and make a very light application, or dilute with flour and apply more freely.

If thoroughly disseminated in the air of a room it will soon bring to the floor all the flies and mosquitoes therein. A good way to rid a room of flies is to make the application and close the room tightly for the night. Then in the morning sweep up the flies and burn them. If they are not destroyed in this way after being stupefied, many will finally overcome the action of the powder and live.

25. TOBACCO.

Tobacco has long been used in one way or another for the destruction of insects. Its chief use seems to be for the destruction of animal and plant lice. When slowly burnt the smoke may be utilized for the destruction of lice on plants in greenhouses or window gardens. In the form of a fine dust it is often effectual in ridding plants of flea-beetles, and in the form of dust or stems is probably the best remedy we have for woolly aphis on the roots of apple trees.

A decoction made by boiling tobacco stems in an amount of water sufficient to cover them is destructive to plant lice (Aphididæ) and to lice upon cattle. Tobacco, very finely powdered, in the form of

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*This formula and directions are copied from "*The Spraying of Plants*," by Lodeman.

snuff, may also be used dry against the same insects. It is best to first spray the insects with water.

26. SULFUR.

Everyone knows of the use of sulfur fumes for the destruction of animal life. Sulfur is specially destructive to "red spiders" and "brown mites," and may be applied as flowers of sulfur, dry, through a blow-gun of some sort, or mixed in water or soap solutions in the proportion of an ounce to a gallon of the liquid and applied as a spray.

27. HOT WATER.

Water heated to 125 to 135 degrees Far. kills very quickly any insect that is put into it, but is harmless to plants unless they are kept submerged for a long time. Lice, especially those on roots, may often be killed conveniently with hot water.

SUBSTANCES THAT KILL BY BEING INHALED.

There are two insecticides of this sort that are of special importance. As both are destructive to vegetable life also, care must be had in their use that they are not applied in strengths that will destroy the plants. It is important that tents, rooms, or other receptacles in which objects are placed for fumigation, be as nearly air tight as possible.

28. CARBON BISULFIDE; "FUMA."

This is a clear, extremely volatile liquid with a very disagreeable odor. The fumes are heavier than air, so that it is always best to expose the liquid in the upper part of a building, or other receptacle, containing objects to be treated. The fumes are explosive also when mixed with air, so that great care must be taken not to bring fire near them.

For the purpose of fumigating a building or other inclosed space containing growing plants, not over one pint of the liquid to 1,000 cubic feet of space should be used. For the destruction of insects in seeds, carpets or clothing it may be used much stronger.

To destroy ant hills, thrust a sharp stick down into the hill to a depth of eight or ten inches and then remove it and pour in two or three ounces of the carbon bisulfide; fill the hole with earth by stamping on it, and then throw over the hill a wet blanket to hold down the fumes. Allow the blanket to remain for a half hour at least, and the ants will be dead. If the hill is a very large one it would be well to make two or three holes for the carbon bisulfide.

To kill prairie dogs, pour three or four ounces of the liquid on a ball of cotton and roll the latter down the prairie dog hole and quickly fill the mouth of the hole with dirt.

For the destruction of the woolly-louse of the apple, thrust a crow-bar or other sharp instrument into the ground to the depth of one foot and at a distance of two feet from the crown of the tree and upon three sides of the tree. In each of these holes pour one ounce of the carbon bisulfide and close the holes quickly with damp earth. This is a cheap and effectual remedy and, if care is taken to have the holes made two feet from the tree and to have only about an ounce of the liquid put in a hole, there will be no danger of killing the trees.

This substance is expensive when purchased in small quantities at a drug store. It may be obtained quite cheaply if purchased in 50-pound lots, from Mr. Edward R. Taylor, Cleveland, Ohio. Write for prices.

29. HYDROCYANIC ACID GAS.

This gas has come into very general use, particularly in the orange growing sections of the country, for the destruction of scale insects. It may also be used for the destruction of insects in mills and in dwellings and in closed receptacles generally. Some of the best nursery men have adopted the plan of fumigating all their nursery stock with hydrocyanic acid gas before shipping to their customers.

The chemicals of which this gas is made are cheap and are used in the following proportions:

Potassium cyanide (of 98 per cent. purity)	1 ounce
Commercial sulfuric acid	1 ounce
Water	3 ounces

The above quantities are sufficient for a space of 100 cubic feet for the fumigation of dormant trees and plants (nursery stock). It may be used in the same strength, or even stronger, for the fumigation of mills, houses, clothing and the like.

The tent, building or receptacle in which the fumigation is to take place, should be as tight as possible. The less wind there is the better, if the fumigating room is not very tight.

The gas should be generated in an earthen jar, or wooden bucket or tub. *The chemicals must be added in the following order:* First put in the water; then add the acid; and, after the water and acid have mixed, add the potassium cyanide. A good way to add the poison is to have it tied in a paper sack and placed upon a piece of board over the dish containing the acid and water, with a string attached to the sack and passing to the outside. Then, when everything has been made tight, a pull on the string will precipitate the sack of cyanide in the acid and a rapid escape of the poisonous fumes (HCN) will immediately take place, causing violent bubbling of the liquid. Filling ones lungs with these fumes would cause almost instant death, so that great care must be taken not to breath them. Fumigating rooms must be arranged so that doors or windows of some sort can be raised from the outside quickly. Then a thorough airing must take place before anyone enters.

It would require considerable space to give full directions for the fumigation of orchard trees, and, as there is little likelihood that such fumigation will be called for in Colorado for some time to come, I shall not take space to describe the process here. Those specially interested can obtain bulletins giving full directions from the Department of Agriculture, Division of Entomology, Washington, D. C. Full directions can also be obtained in a book entitled "Fumigation Methods," by W. G. Johnson, and published by Orange Judd Co., New York. Figs. 16 and 17 are from this book.

SUBSTANCES THAT REPEL.

There are a number of substances that are more or less useful for the purpose of driving insects away from places where they would do harm if unmolested. I give below a few of the most important.

30. NAPTHALINE, GUM-CAMPHOR, AND MOTH BALLS.

Napthaline crystals are much used in insect boxes and in boxes or trunks where furs, feathers or woolen goods are kept, for the purpose of keeping out insects that feed on these animal products. It is probably the best single chemical that can be used for this purpose. Gum-camphor is also much used for the same purpose and moth-balls are a combination of these two volatile substances. These materials cannot be used to kill insects, but only to repel them.

31. TOBACCO.

Tobacco, in the form of dust, or otherwise, is often used for the same purpose as the preceding, but to be effectual must be used quite freely.

32. ASHES.

Ashes, particularly from wood, are frequently used to dust upon plants after a rain or while the dew is on and often result in the insects disappearing. Particularly is this true in case of flea-beetles and the cucumber beetle when feeding upon leaves. Ashes do not kill the insects, but they make the food distasteful, so the insects are driven to other plants.

33. LIME, PLASTER, AND ROAD DUST.

These substances are also used like ashes as repellents, but are of little or no use for the destruction of insects.

INSECT TRAPS.

There are many methods of trapping and destroying insects. One of the most common is the use of bright lights exposed at night.

34. LIGHTS.

The usual plan is to place a light over a dish of some sort that contains water with coal oil on top of it. Many night-flying insects are attracted by lights and may be destroyed by devises of this kind, but there are also many insects that fly at night that are not attracted by lights. Such an insect is the codling moth, though light traps are often recommended for its destruction. Among those insects that are readily attracted by lights might be mentioned tbe adults of the army worm, of the various cut-worms, the garden web-worms and the corn or boll-worm.

It is not infrequently the case that more of the beneficial insects are destroyed than of destructive species, and it is quite doubtful if lights are often of any considerable importance as a means of lessening the injury to crops by the destruction of insects.

35. SWEETENED WATER, CIDER, VINEGAR, ETC.

Some insects are attracted in considerable numbers to such substances as the above, but it is very seldom that the benefit derived from them will pay for the trouble and expense of using them. Mr. David Brothers, of Edgewater, Colo., reported excellent success capturing moths of the fruit-tree leaf-roller with weakened vinegar in pans in the orchard, and the codling moth is attracted to some extent to a mixture of molasses and vinegar placed in apple trees. The advantage of such baits for the capture of insects is usually greatly overestimated by those who use them.

36. BANDAGES.

Heavy cloth or paper bands placed about the trunks of apple trees are quite useful for the capture of the larvæ of the codling moth that are leaving the apples and going in search of a suitable place to spin their cocoons. Burlap bands are cheap and seem to be as good as any. The writer took 1,481 codling moth larvæ under a single burlap band one season. Old gunny sacks cut into strips serve as well as anything. The band should be not less than four inches wide and should be composed of three thicknesses of the cloth.

The bands should be wrapped loosely about the trunks, the ends overlapped and held in place by a single carpet tack pushed in with the thumb.

If used against the codling moth they should be removed once in a week or ten days for the purpose of killing all the worms and then replaced.

The bands should be placed on the trees about the 10th of June in the warmer parts of the State, and about the 25th of June in the northern parts.

Heavy paper may be used in place of the cloths.

The peach twig-borer can also be taken under these bands.

Bands of paper or wire screen are sometimes wrapped about the entire trunk to prevent the entrance of borers, as shown in Plate IV., Figs. 2 and 3.

37. HOPPER-DOZERS OR HOPPER-PANS.

For the purpose of catching jumping insects, especially grasshoppers, the hopper-dozer or hopper-pan is most useful. There are different methods of constructing these pans. A form used by Dr. Riley and illustrated by him many years ago is shown at Fig. 2. The pan in the illustration is entirely of sheet-iron, and is drawn across the fields by two men or two horses. In the bottom of the pan is placed a small amount of water with kerosene on top of it. All grasshoppers that come in contact with the oil die. The back of the pan may be extended by means of stakes at the corners and a strip of cloth hung between them. Such an extension catches many grasshoppers that would otherwise escape.

38. STICKY SUBSTANCES.

Bandages of sticky substances, such as printer's ink, "Dendroline," or "Raupenleim," or even cotton batting, are sometimes used to prevent insects from climbing trees. Where oily substances are used it is safer to put them on a bandage of stout paper, which is then wrapped about the trunk of the tree.

THE APPLICATION OF INSECTICIDES.

IN THE DRY WAY.

The upper surface of the leaves of all low plants can be easily treated with a dry insecticide by dusting it upon them through a cheesecloth, or other thin muslin sack, held in the hand. There are also various appliances upon the market for the distribution of powders. One of these that is very convenient for filling the air of a room with dust to kill flies, or for the application of powders to low herbage, is shown in Fig. 15. It can be had of Thomas Woodason, 451 East Cambria Street, Philadelphia, Pa.

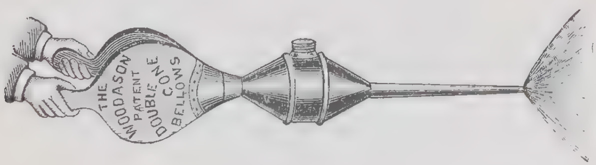

FIG. 15.—Dust-sprayer.

The Hillis Dust Sprayer Co., St. Louis, Mo., manufacture a

"dust-sprayer" large enough to distribute dry insecticides through trees of the size of an ordinary apple tree.

IN THE WET WAY.

There are so many manufacturers of spray pumps and nozzles of all descriptions that it is impossible to point out any make as being the best. The illustrations here given are for the purpose of giving the reader an idea of the kind of a pump that will be needed for his work. Each must be his own judge as to the quality and price of the pumps offered him.

Fig. 16.—"Faultless" Hand Atomizer.

Fig. 16 is an illustration of the "Faultless Sprayer, manufactured by F. E. Myers & Bro., Ashland, Ohio. It is inexpensive and will answer well where only a few small plants are to be treated.

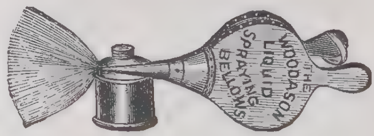

Fig. 17.—Bellows Atomizer.

Fig. 17 shows a form of atomizer, having a similar use, also sold by Woodason, of Philadelphia.

PUMPS.

Pumps with metal valves should be obtained for the application of insecticides or fungicides in liquid form, as the materials used harden or decompose leather valves so that they last but a short time. If the pump is to be used with a tank or barrel it is also important to have some kind of attachment that will keep the liquid agitated so the materials in suspension will not settle. A common error is to purchase a pump of too small capacity, because it is cheaper. A smaller, cheaper pump usually means less accomplished in a day with the same help, but with a greater expenditure

of energy. And then, it is often important to complete the spraying in as short a time as possible after it is begun. To do this, a pump of large capacity with two or more leads of hose is necessary. The hose to which the nozzles are attached should be as light as possible and still have the requisite strength—a hose of good quality with heavy wall, but small caliber. Fig. 18 illustrates a form of bucket pump manufactured by The Deming Company, Salem, Ohio. Bucket pumps are sold by different dealers at prices ranging between about $2.00 and $8.00 in price. They are suitable for use among vegetables, shrubbery and all low plants, but should not be purchased for orchard work if one has more than a very few trees to treat. In the small sprayer shown at Figure 19 the liquid is forced up by means of air pressure. Such a pump is often convenient when a person is compelled to do his spraying alone. This sprayer also has an oil attachment, so that water and kerosene may be applied mixed without the trouble of making an emulsion. This pump is manufactured by Leggett & Brother, New York City.

FIG. 18.—Bucket Pump.

FIG. 19.—Leggett's Air-pressure Pump.

Fig. 20 shows a form of air-pressure sprayer sold by the North Jersey Nurseries, Springfield, N. J.

Many prefer some form of the knapsack sprayer for the treatment of low plants. At Fig. 21 is shown one of these sprayers as sold by William Stahl, Quincy, Ill. Knapsack sprayers are also

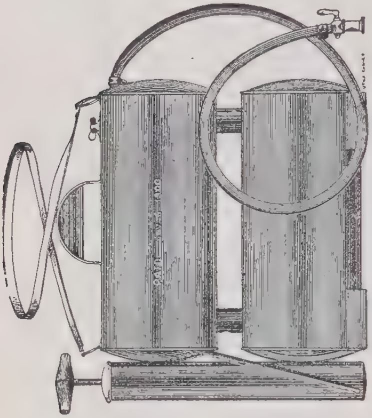

FIG. 20.—Another form of Air-pressure Pump.

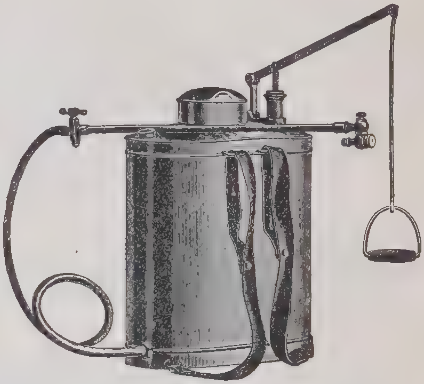

FIG. 21.—Knapsack Sprayer.

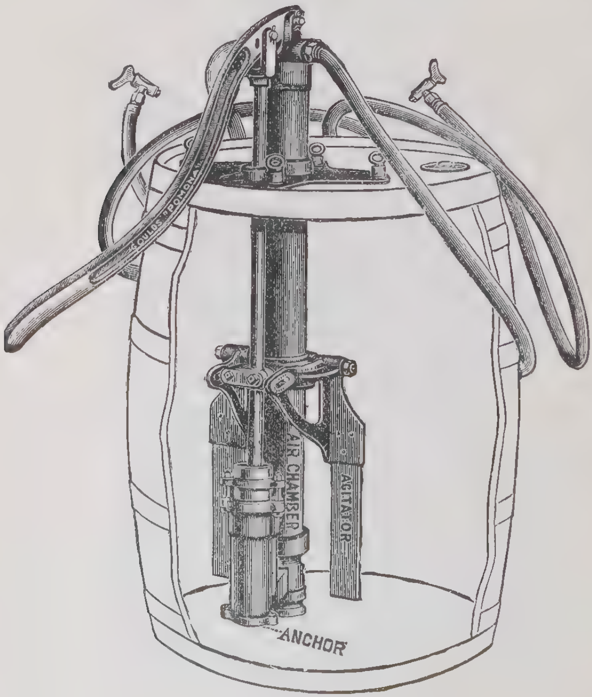

FIG. 22.—Barrel Pump.

made with an oil tank attached so as to spray kerosene, or petro-

leum, in a mechanical mixture along with water, so as to do away with the need of making an emulsion.

For the treatment of small orchards a barrel pump is generally used. One of the best of these is Gould's "Pomona" spray pump shown in Fig. 22. The pump carries two leads of hose and has a patent agitating arrangement within the barrel. It is sold by The Gould Manufacturing Co., Seneca Falls, N. Y.

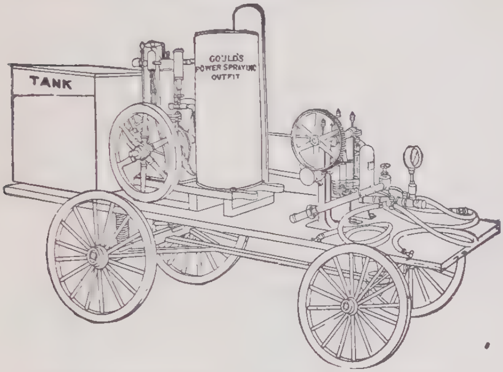

FIG. 23.—Power Pump. Run by Gasoline Engine.

Where a large amount of orchard spraying is to be done larger pumps and tanks should be used. Fig. 23 shows a gasoline power sprayer attached to a large wagon tank. Such sprayers will easily run four leads of hose and keep up a high pressure. Without a good pressure it is impossible to throw a fine and forcible spray. The power sprayer here shown is also manufactured by The Gould Manufacturing Co. There are many other companies manufacturing spraying apparatus. Their advertisements will be found in agricultural papers. If anyone is thinking of purchasing an expensive spraying outfit he should obtain catalogues and prices from several manufacturers or dealers and then purchase where he thinks he can do best.

HOW TO SPRAY.

The first requisite for a good job of spraying is a pump that will give plenty of pressure in the hose. Then, if one has a good spraying nozzle and a liquid that is free from solid particles of a size to clog the sprayer, there will be no difficulty in getting a good spray. A very fine spray is most economical of material and, for an even and thorough distribution, is best. Care should be taken, also, not to continue the spraying until the little drops that collect on the foliage unite and run off, carrying the poison with them. In some cases, however, as when spraying the first and second times for the codling moth, the writer prefers a rather coarse spray and to continue until the calyces of the forming fruits have all been thoroughly drenched without regard as to how much the liquid is dripping from the foliage. The medium coarse spray is preferred for this work, because the larger drops carry better into the blossoms, or calyces, of the apples.

The "Seneca" nozzle sold by the Gould Manufacturing Co. and shown at Fig. 24 throws a good coarse spray. The "Bordeaux"

nozzle shown at Fig. 25 and sold by The Deming Co. is one of the

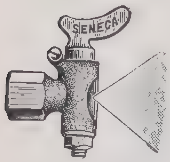

FIG. 24.—Seneca Nozzle.

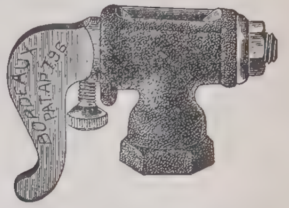

FIG. 25.—Bordeaux Nozzle.

best nozzles for either coarse or medium fine spray. For a very fine, misty spray I know no nozzle that equals the "Vermorel." This nozzle is mounted singly, as shown in Fig. 26, or in batteries of two, three or four nozzles combined. A battery of two nozzles is shown at Fig. 27. Figs. 26 and 27 are from the catalogue issued by the Gould Manufacturing Co.

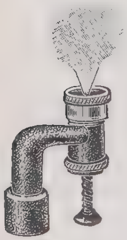

FIG. 26.—Single Vermorel Nozzle.

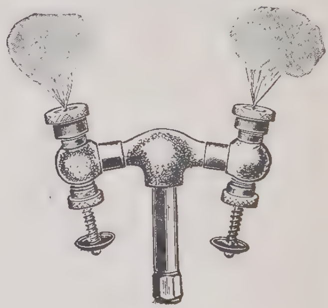

FIG. 27.—A Battery of two Vermorel Nozzles.

For farther information in regard to insects or insecticides address the Experiment Station. When making inquiries concerning insects, send samples of the insects and their injuries whenever possible.

Bulletin 72. August, 1902.

The Agricultural Experiment Station

OF THE

Agricultural College of Colorado.

A Soil Study.

PART IV.

THE GROUND WATER.

—BY—

WILLIAM P. HEADDEN.

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The Agricultural Experiment Station,

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A Soil Study:

Part IV. The Ground Water.

By WILLIAM P. HEADDEN, A. M., Ph. D.

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§ 1. I have presented the results of our experiments and observations upon the effects of alkaline conditions of the soil upon crops, upon the sugar beet in particular, in Bulletins 46 and 58, forming Parts I and II of this study. In Part III, Station Bulletin 65, I have presented the subject of the soil, and the effects of cultivation upon it, from both the chemical and physical standpoint. The conclusions reached in these bulletins have been summarized in the respective publications and will not be reproduced in this place, as reference can easily be made to the statements of them in the originals, which are fuller than could be made here.

SOME OBSERVATIONS ON ALKALIZATION.

§ 2. The statement made on page 3 of Bulletin 46, relative to the general question of alkalization in Colorado is, I believe, correct. I would state the question even more explicitly, especially for the eastern slope of the Rocky Mountains, for I am convinced *that the only question of alkali that we have resolves itself into one of drainage, and beyond this, there is no alkali question for us.* I believe this to be true of the western as well as of the eastern portion of the State.

§ 3. I am aware of the fact that some sections of the State have an abundant supply of alkali salts, but their presence and whatever injurious effects they may have produced, is due principally, if not wholly, to the lack of drainage, which, in many instances, has been made more apparent and its effects greatly augmented by over-irrigation. An immoderate use of water, especially when no regard is had for drainage, the peculiarities of the soil or the requirements of the plants, can prove as disastrous to the agriculture of a section as other naturally adverse conditions. This cause of trouble will be lessened in all parts of the State as the de-

mand for water approaches the limit of the supply and an economic and intelligent use of it is forced upon the agriculturists. As an illustration I may give the following facts which were stated to me—not for the purpose for which they are here used—by a person conversant with them: In a certain section of the State the water table was about 18 feet below the surface and the water was usable, though not good. A few years after the irrigating ditch, which furnished a super-abundance of water, had been built, the water plane had raised by 15 feet or more, with the result that the depressed portions of the country were being drowned out. The water, which had become heavily laden with the alkalies, was much less desirable than formerly, or wholly unfit for use. The people, as a matter of course, did not take it kindly when the writer insisted that there were two contributing causes to this state of affairs, over-irrigation and lack of drainage, and that the remedies were simple if feasible. The first was to apply less water, which could easily be done; the second, to drain the land, which could not easily be done.

§ 4. The character of the underlying strata, the presence or absence of a hard pan, often contributes to bringing about bad drainage conditions, but this was not the case in the above instance, and I think that it is not very generally the cause in any section of this State. I have seen no occurrence of alkalies in this State where their accumulation was not due to these causes, usually to the lack of drainage, the alkalies accumulating in depressions with no outlet which serve as collecting places for the water running off of or draining from the higher ground, or along water courses where the lowness of the land and character of the vegetation prevent proper drainage.

THE CONDITIONS OF THE PLOT EXPERIMENTED ON.

§ 5. The plot of ground chosen for our experiment was in the worst condition of any plot at our disposal. It was quite wet, had no hard pan, but a stratum of clay at a depth of about 5 feet, underlain by gravel. It was not drained, though a tile drain had been laid to the west, south and east of it, but at so great a distance that it failed to perceptibly affect the condition of this plot. An irrigating ditch flows within 50 feet of the east end of the plot, and one perhaps 150 feet from the west end of it, both being at a higher level than the plot itself, which has a slope to the eastward of six inches in a hundred feet. The ditch passing the east end of the plot was, we feared, an important factor. We will subsequently state the results of our observations made to determine to what extent this ditch influenced the water level of the plot.

§ 6. Such were the general conditions of the ground chosen

to experiment on, and which was chosen as representative of much land in Colorado which is neither so wet as to be untillable nor so strongly alkalized as to be hopeless, and yet was strongly enough impregnated with salts to yield, under favorable conditions, incrustations reaching a half inch in thickness.

§ 7. Parts I and II of this study deal exclusively with the effects of these conditions on the growth and composition of sugar beets, the crop chosen to grow on this land, because we thought it probably more tolerant of the conditions than any other crop which would at the same time serve the other purposes of our study.

§ 8. Part III deals with the soil, giving an account of the mechanical and chemical effects resulting from our cultivating and manuring it. In this bulletin, Part IV of our study, we shall present the results of our observations on the ground water, the changes in the water used for the purpose of irrigating, the salts removed, etc. I shall confine myself in this bulletin to the subject of water, as in Part III I confined myself to the subject of the soil.

§ 9. I have stated the general condition of the plot at the beginning of the experiments; I have stated the reasons which induced us to choose this plot of ground as well as the crops to be grown thereon; and in Part III I have given the condition of the soil at the end of our experiments, which is summed up by stating that the store of plant food in the surface soil, taken to a depth of ten inches, was actually increased. This, however, was the lesser part of the improvement, the greater part lay in the betterment of the general conditions, whose best features cannot be shown by chemical analysis or expressed in any formula. The strongest and most interesting point in this connection is that the conditions of water supply and drainage have remained the same throughout the experiment. The ground has subsequently been drained, in part, at least.

§ 10. The amount of water in the soil was not determined for the reason that the soil was excessively wet, the water table being at times within a few inches of the surface, and in parts of the plot, seldom more than three feet six inches below it, while in the highest portion of the plot it was only six feet from the surface at its lowest stage. One would think that, under such conditions, irrigation would not be needed; that the sub-irrigation would be sufficient. We did not find this to be the case. The explanation probably lay in the fact that the root system accommodated its development to the conditions obtaining during the earlier and greater portion of the season, and when the water table fell the surface soil, owing largely to its unfavorable mechanical condition, dried out rapidly to a greater depth than a soil in good mechanical

condition would have done, causing the plants to suffer. The plant, too, may have become more sensitive to a lack of water, owing to the usually large supply of it. Whether this is the explanation or not, we had to irrigate two out of three seasons, and while we irrigated the third season also, it was probably not actually necessary so far as the growing of the beets was concerned.

§ 11. The height of the water table in the plot was referred to a plane 10 feet below our bench mark. The wells were designated as A, B, C, D, E, F, G and H; their respective heights, referred to the same plane, were: A, 9.41′; B, 11.12′; C, 11.23′; D, 12.71′; E, 7.24′; G, 9.59′. The heights of F and H were not determined; these wells were dug for special purposes, which it would be out of place to explain at this time. Wells A, B, C and D were the principal ones and were dug at intervals along the central line of the plot, which had a width of 50 feet and a length of 600 feet. The distances between the wells were not equal. Well A was the most easterly one, and was 130½ feet from the center of the ditch; B was 150 feet west of A; C 175 feet west of B, and D 160 feet west of C. The surface of the plot at D is 3.3 feet higher than at A; the surface of the underground water is 1.83 feet higher. The distance from A to D is 485 feet, accordingly the surface of the water table has a fall of 1.83 feet in 485 feet, while the surface of the plot has a fall of nearly twice as much. The greater height of the water table at the west end is probably due to the friction of the flow, and is but little modified by the contour of the surface.

§ 12. I suppose that the escape of the ground water is to the eastward, though I have no direct proof of this. There is a drain running from a depression west of the plot, making a wide curve and passing again to the east of it. This drain was put in in this shape to cut off seepage from higher lying land to the westward and to drain a still lower lying portion to the east of the plot. I have elsewhere stated that it accomplished its purpose but partially.

§ 13. The daily records of the height of the water plane show that it varied quite uniformly throughout the plot—the wells as a rule rising and falling together. At times there would be a rise in the water table when no rainfall had taken place and no land had been irrigated which could affect the height of the water plane in this plot. Such rises in the water plane were probably due to meteorological conditions. A rainfall of a fraction of an inch also affected it, owing to the nearness of the plane to the surface, by modifying the capillary force within the soil. A rainfall of 0.28 of an inch at 4:30 on the 8th of July was followed on the 9th by a rise of from 0.74 to 0.90 of a foot in the water level; but a rainfall of 0.9 of an inch on the night of the 9th produced a mixed result,

which was probably due to the varying character of the soil and the air contained in it. On the night of July 18th a rainfall of 0.21 of an inch occurred, and the water plane on the morning of the 19th had risen rather more than 0.40 of a foot as an average for the four wells. No further rainfall occurred, and the weather conditions remained favorable for observing how long the effect of such a rainfall would remain noticeable. On the morning of the 20th the level had fallen about 0.2 of a foot, and by the morning of the 22d it had attained the same level that it had on the 18th, prior to the rainfall. On the 23d it was a little lower, but rose again on the 24th.

§ 14. The height of the water plane oscillated throughout the season, owing to the causes already mentioned, and was also influenced directly by irrigation of higher lying land. The record for 1898 was a weekly instead of a daily one, and the minor changes due to meteorological causes were largely eliminated, and only the larger ones, such as were caused by drainage, or continued meteorological conditions, are shown.

§ 15. There was a rise of the water table throughout the plot during the month of February, 1898, of about 0.5 of a foot. The total rainfall was only .08 of an inch. During the month of March there was a fall in the water level. There was a greater rainfall than in February, though it was still insignificant. This oscillation was a longer one than is due to the usual meteorological influences or to irrigation, besides no irrigation was being practiced at this season. It may have been due to freezing and thawing and to the consequent change in the freedom of the circulation of either the water or the air within the soil.

§ 16. I supposed that the presence of the irrigation ditch near the east end of the plot exercised some influence upon the height of the water level in its immediate neighborhood. In order to observe the extent of this, the height of the water in two wells, A and G, was observed before water was turned into the ditch in the spring, and when no water had run in it for several months. We made no effort to determine whether its influence was by leakage or otherwise. The wells taken under observation were close together, A entering the gravel below the clay, while G did not reach the stratum of clay mentioned as separating the soil from the gravel, and was presumably supplied with water from the soil proper. Well G was not so deep as well A by 2 feet. The distance between the wells was 12 feet. The water in well G usually stood a little higher than in well A, whether there was water in the ditch or not. It should be added, for a better understanding of the conditions, that the ground on the east side of the ditch sloped gently to the eastward and lay between the ditch and the drain

already mentioned. Water was turned into the ditch late in the afternoon of April 20th. By 6:15 p. m. of the 23d the water plane had risen 0.31 of a foot in well A, and 0.30 of a foot in well G, the former being 130½ feet and the latter 142½ feet distant from and west of the ditch. No rain had fallen during the preceding 17 days, and the effect observed was probably wholly due to the influence of the ditch, and it is doubtful whether the effect of the ditch upon the height of the water plane was ever much greater than is here indicated, 0.30 of a foot.

§ 17. The total solids and the chlorin present in the water before and after the rise showed a decrease. If the rise were due to unfiltered water passing in from the surface, or even near it, as from the bottom of the ditch, this result would stand alone and in contradiction to the results observed when the level of the water had been raised by a copious rainfall or by the application of irrigation water. In both of these cases the total solids and the chlorin were greatly increased, but not in any definite ratio—the increase in the amount of chlorin being more rapid than that of the total solids.

§ 18. The decrease in the total solids held in solution suggests the damming back of the underground water and a rising of water which was usually below the clayey stratum. The principal fact on which this interpretation rests is that the water taken from below this stratum was actually poorer in total solids than the water above it. We also attempted to study the effect of a drain run for the most part just outside of and south of the plot, but owing to a variety of causes, the principal one of which was our inability to properly attend to it, this experiment was abandoned.

§ 19. When the water table in this plot had been raised by irrigation it required from 10 to 13 days for it to fall to the level at which it stood before irrigation. The rate at which it fell was very nearly the same throughout the plot and did not reach this level at the west or higher end first and gradually proceed eastward as it would do if there were sufficient freedom of flow and the drainage was from the east end of the plot.

§ 20. It is mentioned on a preceding page that when the water level rose owing to the change in the conditions of capillarity caused by a slight rainfall, it required only about three days for it to recede to its former level, while we state that after an irrigation it required from 10 to 13 days. The two cases are quite different. In the latter case we have displaced the air and filled the soil with water, piling it up on the existing water plane; in the for-

mer we pulled it up by a force which gradually lost its power and permitted it to subside.

§ 21. The general observations on the water level in this plot shows that it is subject to small oscillations due to meteorological conditions, and that there are also oscillations extending over several weeks, the cause of which we have not attempted to suggest, and in addition to these, the accidental ones caused by rainfall or irrigation.

§ 22. The water table in the east end of the plot was seldom at a depth exceeding the height to which water would be raised by the force of capillarity, and in this section the accumulation of alkali was the greatest. This plot gave us throughout its whole extent a good opportunity to study the changes in the character and quantities of salts in the ground water.

TOTAL SOLIDS IN THE GROUND WATER.

§ 23. Samples of the ground water were taken weekly for the determination of the total solids. There seemed to be no relation between the different wells in this respect, their content being determined by the conditions obtaining in their immediate vicinity. For instance, well A, situated in the worst portion of the plot, carried on May 24th 3.6114 parts per thousand; * this quantity fell, with slight fluctuations from week to week till the end of June, when it carried 2.8714 parts. Well B, which was 150 feet west of A, carried at the beginning of this period 2.7843 parts per thousand, which rose to 3.2828 parts by June 21st, and fell to 2.9143 parts by the 28th. Well C carried, May 21st, 2.5000 parts per thousand, on June 28th 2.3286 parts. The changes in the total solids present in well D were almost identical with those observed in the case of well C. The rainfall during this time amounted to 2.08 inches. The height of the water table had varied during this period, but it was almost exactly the same at the end of it as at the beginning, the greatest variation being 0.1 of a foot higher.

§ 24. The cause of this gradual fall of the total solids held in solution by the ground water was probably not due to the influx of ground water from the west carrying a less quantity of salts in solution, for subsequent examination showed that the ground water from this direction, some of which, at least at times, found its way into this ground, was richer in this respect than the ground water usually filling this soil. The above statement that some of this water from the west found its way into the plot merely means that in extreme cases the level of the water table in the plot was affected by

* To convert parts per thousand into grains per U. S. gallon, multiply by 58.334946, into grains per Imperial gallon by 70.0.

it, and not that I assert the actual flowing of this water to the eastward through the plot, for the total lack of agreement in the amount of the total solids in the water of the different wells, there being only an approximate agreement when the wells were only 12 feet from one another, indicates that the change of level was an actual rising and falling due to changes in pressure, mostly hydrostatic, rather than to a flowing in and mixing of other waters. If such took place above the water plane, we should expect to observe effects similar to those produced by the entrance of water from above as in the case of heavy rainfalls or irrigation.

§ 25. I have not been able to detect any pushing along of the water, indicated by the amount of total solids in solution, nor yet by their composition. I thought to test this by the addition of a quantity of a lithium salt into one of the wells, but this experiment was a failure for reasons hereafter given.

§ 26. The water soluble in the soil at various depths with high and low water plane, was not determined, but it is probable that the diminution of the total solids in solution was due to the removal of the salts from the solution and deposition of the salts in tne upper portions of the soil. The organic matter held in solution fell with the total solids, judging by the loss on ignition, allowance being made for water which may have been present in gypsum.

§ 27. The irrigation applied on June 29th was not a copious one, because we had only a small quantity of water at our disposal. Its effect on the height of the water plane did not reach its maximum for several days. It was followed by an increase in the total solids in the water, but this was so irregular in its amount and in the time of its appearance that it is difficult to give an exact statement of it beyond the general one that an increase followed it. On the day previous to the application of irrigation water, the total solids in the water of well A were 2.8714 parts per thousand; five days later it carried 3.6871 parts, and twelve days after irrigation it reached 4.4443 parts. This quantity gradually decreased until just before the next irrigation it had fallen to 2.5900 parts per thousand.

§ 28. There was only a general similarity in the deportment of the wells, the individuality of the separate wells being very marked. In well B, for example, the total solids present just before irrigation amounted to 2.9143 parts per thousand, which rose to 3.1000 parts, fell to 3.0000 parts, and then rose continuously for the next eight weeks while they were falling in the other wells. The subsequent, second irrigation caused an increase in the total solids in the water of all the wells, but it was very much less in

that of well B than in that of wells A and C on either side of it. This was not influenced by the height of the wells, for A was 0.70 of a foot lower, and C 0.77 of a foot higher than B. This irrigation caused an increase of 1.2286 parts per thousand in the solids in A, 2.7714 parts in that of C, and rather less than 0.0428 parts in that of B. In the case of well D there was an actual depression of the solids by 0.0714 parts per thousand, but this was probably due to the running in of water from the surface. The subsequent deportment of this well was similar to that of well B.

§ 29. The total solids in wells A and C increased suddenly after the irrigation and then fell again, reaching the point at which they stood prior to the irrigation in about three weeks. In wells D and B the total solids increased throughout this period, at the end of which the water in B showed its maximum content for the season, 4.2143 parts per thousand; in D, however, they continued to increase for three weeks longer before reaching their maximum for the season of 3.6986 parts. The maximum quantity of salts in solution in the water of well A was reached immediately after the irrigations, 3.7857 and 3.8143 parts per thousand respectively; the minimum was found in September, 2.7871 parts per thousand; in B the minimum was found in May and the maximum in September, more than three weeks after the irrigation. In C the minimum was found in June, immediately before irrigation, and the maximum, 5.1929 parts per thousand, in August, immediately after irrigation. In D the minimum was found in June and the maximum in October, over six weeks after the last irrigation. From October, 1897, till May, 1898, the total solids in the water gradually decreased, with only a few increases which were slight and immediately lost. The net result at the end of the year was a very slight decrease in the salts held in solution by the ground water. The wells showed the following quantities of salts in solution at the beginning and end of the year respectively: A, 3.6114—2.8714 parts per thousand; B, 2.7843—2.8328 parts per thousand; C, 2.5143—2.0329 parts per thousand; and D, 2.5700—2.0843 parts per thousand.

§ 30. The deportment of well B is not such as one would expect to observe in it judging from its location. Wells A and C were located in wetter and apparently more strongly alkalized sections than well B, and the sample of the soil taken near B showed the presence of less sulfuric acid and soda than those from near the other two wells, yet the water from this well is richer in dissolved salts throughout the year than the others, excepting that of well A for the month of May alone.

§ 31. When the height of the water plane is raised by irrigation water, or a continued rainfall, the percolating water carries the

soluble salts with it into the ground water, and an increase in the salts dissolved in the ground water is simultaneous with the rise of the water table. It is evident that this rise is due to the piling up of water on a portion of the general water plane represented by the irrigated plot, and would not take place if the water could flow perfectly freely through the soil, which it does not do. This does not fully state the facts in regard to the increase and decrease of the salts in the ground water; for while it is true that there is an increase in the salts concurrent with the rise of the water table when it is due to the application of water to the surface, and a subsequent fall, usually quite a rapid one, we have the solids in the water of two of the wells showing a different course. The solids in that of wells B and D began to increase immediately, or very soon, after the irrigation of August 18th to 20th, and continued to increase for several weeks, though the water table was steadily falling during this time, which in the case of well D was six weeks. This is the more remarkable for in both these cases the maximum reached was the maximum for the season. In the case of the other two wells the results were in the opposite direction. In the waters of these wells the amount of the dissolved salts reached their maximum for the season immediately after the irrigation and fell within four weeks to their minimum for the remaining months of the year, and within 0.1571 parts per thousand of the minimum for the whole season. The cause of this difference is not suggested by a consideration of the rate at which the water table fell. The height of the water table above the reference plane was not the same in the different wells, and there were slight variations in the rate of fall, but neglecting these irregularities, the rate of falling was very nearly the same, so that the rapid decrease in the amount of the total solids in the water of wells A and C was not probably due to any drainage, affecting these wells to a greater extent or in a different manner than it did the wells B and D. The conditions of diffusion obtaining in the different wells probably contributed to the observed results. The composition of the solids contained in these waters will be given subsequently.

§ 32. In this irrigation, as well as in the preceding, the head of water at our disposal would not permit of our attempting to flood off any salts, and practically all the salts which were on the surface at any given place were carried back into the soil, so that there was but little, if any, transporting of salts even for a few feet in the direction of the flow of the water. It follows that any removal of salts during this season was by drainage.

§ 33. In the following season, 1898, the conditions were quite different. During April, and especially during May, there were frequent light rains. The water table was rather higher at the west

end of the plot and lower at the east end than in 1897. The average height of the water table at the west end of the plot for May, 1897, was 9.80 feet, and for the same month in 1898 it was 9.98 feet for the east end; for May, 1897, it was 8.11, and for May, 1898, 7.55 feet. The rainfall in the two years differed both in its amount and distribution; there was also another changed condition, the plot had been divided into sections 100 feet long by 25 feet wide, and the alternate sections had received a heavy dressing of manure. These conditions undoubtedly had an effect upon the movement of the soluble salts in the soil and also upon the salts themselves.

§ 34. There was a remarkable change in the amount of the total solids contained in the waters of wells A and C between May 16th and 23d, each containing less by 14.3 parts per thousand on the later date. The waters of the wells contained from 3.57 to 5.71 parts per thousand more total solids on May 24, 1898, than on this date in 1897, except in the case of well D, the water of which contained 3.43 parts per thousand less.

§ 35. An examination of the results obtained in 1898 corroborate those of 1897, *i. e.*, that as a rule, the solids in the waters fell as the water table fell, and that a sufficient rainfall or an application of water to the surface was followed by an increase in the amount of salts held in solution by the ground water.

§ 36. The amount of water necessary to raise the height of the water table and at the same time produce an increase in the amount of the salts in the ground water was not observed. I have already stated that a rainfall of a few tenths of an inch was followed by a disproportionate rise in the height of the water table. In the particular instances referred to we unfortunately made no determination of the total solids immediately before and after the change of the water level.

§ 37. In May, 1898, there were nine days on which no rain fell. The aggregate rainfall for the 3d, 4th and 5th was 1.66 inches, this was followed by a rise in the height of the water table, and though there were daily light rains, except on the 10th, until the 16th the water table fell by 0.2 of a foot. In this interval 0.69 of an inch of rain had fallen, 0.22 and 0.24 of an inch being the largest amounts for any one day, an amount which under other conditions had been sufficient to cause a rise.

§ 38. The total solids present in the waters of wells A and C were very high at this date, the 16th, containing 6.1043 and 4.3414 parts per thousand respectively, while those of wells B and D were much lower, 2.9000 and 2.1000 respectively; but seven days later they had fallen in wells A and C and risen in wells

B and D. A little rain had fallen during the week, and the wells, A excepted, were lower than on the 16th.

§ 39. On June 3rd, 4th and 5th we had a rainfall aggregating 1.82 inches, which under the conditions prevailing at that time might have wet this soil to a depth of 5 inches. The water capacity of this soil, air dry, ranged from 36 to 51 per cent. The actually observed rise in the water table ranged from 0.32 to 0.95 of a foot, and the waters of the different wells showed an increase in the total solids present. The increase in the case of well B was slower than in the others. The greatest difference was shown in the case of Well C, where it amounted to 1.0630 parts per thousand. The water table and the total solids had both begun to fall by the 13th, or seven days after the last rainfall.

§ 40. The rising of the water table at times when there had been no rainfall has already been mentioned, as has also the effect of a slight moistening of the previously dry surface upon the height of the water table, but here we have the effect of 1.82 inches of rainfall upon the height of the water table reaching the considerable amount of 0.95 of a foot, or 11.4 inches, while the amount of water which fell was not sufficient to wet this soil for more than 5 inches. The amount of the rise in the different wells varied considerably, as did the increase of the total solids. The former is probably due to the capillary condition of the soil at the different places, and the latter, partly to the solution of salts out of the soil through which the water rose and partly to changes in the conditions of diffusion, for the smallest change in the amount of total solids was not in the well that rose the least, nor in one which was usually low in total solids.

§ 41. The increase in total solids present in the ground water was not always accompanied by an increase in its height. Our observations on the relation of these—increase in height of ground water and total solids contained—are not quite consonant with one another, but they agree that the effect of the addition of considerable quantities of water applied to the surface is to increase the amount of salts in solution. Sometimes the increase in the amount of the salts in solution and that in the height of the water plane fell together, but at other times they did not.

§ 42. The influence of the changes in the water level, due to very light rains or other meteorological causes, was not marked enough to be noted without special study.

§ 43. The solids in the ground water during the season 1898, from May 24th till the end of October, were a little higher during the first two-thirds of the season, but lower during the last third, than in 1897; the water level was also very low, well D go-

ing dry about September 1, and B a month later, October 1. The differences in the individual wells were the same as in 1897, except in the extent of their variation.

§ 44. No attempt was made in 1899 to continue the study of the relation of the height of the water table to the amount of total solids contained in the water.

§ 45. The question whether the height of the water in the wells corresponded with the height of the water table in the soil was repeatedly suggested. Investigation showed that, for all of our purposes, it was safe to consider them the same.

§ 46. The matter was apparently different with the total solids present in the soil and well waters, especially in newly made holes in the soil, in which the solids were higher than in water from the near-by wells. This was not due to rain water falling directly into the wells, for they were covered to prevent this, nor to its running in from the surface, for the tiles which formed the lining of the wells projected above the surface sufficiently to escape this danger. The difference in the amount of salts present in the soil and well waters varied more than I expected them to. In one case, the water table being very high, within 18 inches of the surface, the difference in the amount of the total solids in the water taken from the soil and from the well, well A, was 2 6286 parts per thousand. In another portion of the plot where the water table was not so near to the surface, and where the soil was very different, the difference in the amounts of the total solids was only 0.4714 parts per thousand.

§ 47. It was unfortunately not feasible for us to determine whether the water drained into the wells from the surrounding soil, higher than the water plane, or not. If this took place at all it would seem that it did not drain from a very wide area, the radius of the soil affected must have been very small, or we would probably not have found so great a difference in the total solids present in the soil water and that of the wells. We made an attempt to determine the distance to which an under-drain would affect the height of the water table, and also to determine its influence upon the total solids present in the ground water at different distances from it; but as already stated, the experiment, owing to a variety of causes, was abandoned. The best data that I have bearing on this point was afforded by a well situated about two-thirds of the way from the east end of my plot to an under-drain east of and lower than the plot. The conditions here were in every respect better than in the plot under observation. They had probably not been so unfavorable to begin with, but assuming that they were the results of cultivation and drainage, the drain being about 70 feet from

this well, was to reduce the total solids to less than one-half the amount found in the easternmost well in my plot, 254 feet west of it. This difference held throughout the two years these wells were under observation. These data are not so good as would appear at first sight, for the plot had been under experimental cultivation for several years, five at least, and I have no means of judging to what extent, if any, the changes were due to the direct action of the drain upon this ground.

§ 48. If the water in the easternmost well was part of an eastward flow out of my plot, a large amount of the salts, 50 per cent., had been removed from solution in flowing from the eastern portion of my plot to the well, a distance of not more than 250 feet. The observations, however, upon the dissimilarity of the salt contents of the waters of the different wells justifies a serious doubt as to the existence of a flow through the soil, or if any, it is a slow one and is accompanied by an extremely slow translocation of the salts in the soil. It is certain that the soil has the power of retaining salts, but there are reasons for believing that there are marked differences in the soil in this respect, and if there were a flow, this property of the soil would tend to retard the translocation of the salts. Some facts supporting this view will be mentioned under the subject of drainage.

§ 49. There is another consideration which should be mentioned, the difference in the amount of salts in the water actually in contact with the soil and that in the wells may indicate that the true soil water coming into the wells from the sides may have received an admixture of water coming from below, and from which those salts most readily retained by the soil had been partially removed. If this were the case it would be strongly suggestive of a flow through the gravel, and as the well referred to entered the gravel, the water may have been a mixture of waters, some entering laterally from the soil and others rising vertically from the under-flowing waters. Such might be the case, even when the height of the water in the well and that in the soil outside of the well were the same, or so nearly so that refined means of measurement would have to be used to establish the difference.

§ 50. That the water flowing through the gravel, even if it were water percolating through the overlying soil, should differ in its content of salts from the water in the soil, is in keeping with the observed fact that the total solids present fell as the water table fell. The soil through which the water table fell not having reached its point of saturation for these salts, retained them until an equilibrium between those in solution and those present in the soil had been established.

§ 51. To what extent this well A and all the others were

affected by such mixing of waters has been a serious question throughout this work. The doubts entertained led me to have wells of different depths dug, and to endeavor to determine the extent to which samples of water obtained from slightly different depths taken from the same place and on the same date would differ. The results obtained prove beyond a doubt that the ordinary laws of solubility and diffusion are very radically modified and that the mixing of waters as suggested was improbable.

§ 52. I stated in Bulletin 46, page 5, that the water in the gravel stratum was different from the water in the soil proper. This appears, from the preceding statements, to be almost a matter of course; but there is a broader sense in which it might be the case, as I was at one time tempted to believe, *i. e.*, that the water in the gravel might be practically cut off from the water in the soil by the clayey stratum overlying the gravel, and that the water in the latter came from higher ground and constituted a sheet flowing eastward through it. The possibility that such might have been the case is evident, but I am satisfied that the clayey stratum did not suffice to separate the waters in the soil from that in the gravel, and I am doubtful whether the water from the higher land actually finds its way into the gravel as a distinct course for its flow. That it does not is indicated by our experience in June and July, 1899, when, because of an unusually large supply of water, the land to the west of us was excessively irrigated and the water table in our plot was raised to within eighteen inches of the surface. This water either flowed above the clayey stratum or rose through it.

§ 53. Transportation of the salts laterally through the soil did not, even in this case, seem to take place, for the individuality of the different wells was quite unaffected. Still the results of three seasons' cultivation, irrigation included, shows the removal of large quantities of soluble salts, if the amount of these held in solution by the soil waters be a reliable index. Taking the total solids in the waters of the different wells, ten days after irrigation, August 20, 1897, and August 31, 1899, we have wells A, B, C, and D showing the following total solids respectively in 1897: 30.8571, 35.2857, 3.3429 and 2.6429 parts per thousand; in 1899, 1.7857, 2.7286, 2.8857 and 3.4000 parts per thousand. In the case of Well D, in 1899, we have an increase, but after making allowance for all minor variations and a marked capriciousness in the amount of salts dissolved, there is still evidence of the removal of large amounts of the soluble salts from the soil.

§ 54. The crops, as shown in Bulletins 46 and 58, did not remove these salts, and if they did not remain more generally distributed through the mass of the soil, whereby they would be rendered more difficultly soluble in water, they must have been

removed by drainage even though we were unable to detect the flow.

CHLORIN IN THE GROUND WATER.

§ 55. The amount of chlorin in the ground water was not at any time extremely high. The maximum for 1897 was 0.2400 parts per thousand, unless we include one abnormal result obtained immediately after irrigating the plot, in which case we have 0.3429 parts per thousand; this result stands alone for 1897. The same well, however, in 1898 showed two such variations reaching 0.3143 parts per thousand after an irrigation, and 0.5286 parts on May 16th. The month had been wetter than usual, 2.9 inches of rain having fallen up to this date. With these exceptions this well was not so high in chlorin as two of the other three.

§ 56. The ratio of the chlorin to the total solids in the water ranged from 1:18 to 1:25 for well A from May, 1897, till May 1, 1898; for well B it ranged from 1:15 to 1:19; for well C from 1:18 to 1:22; and for well D from 1:16 to 1:22. In other words the salt, NaCl, found in the water did not, at any time during the year, amount to quite 1-9 of the total matter held in solution by the water and fell as low, in round numbers, as 1-16 of the total solids. In 1898 the ratio of the chlorin to the total solids for the respective wells varied as follows: for A, from 1:13 to 1:21; for B, from 1:14 to 1:16; for C, from 1:11 to 1:27; and for D, from 1:18 to 1:33. The largest amount of salt, NaCl, present equalled 1-7 and the smallest 1-20, or from 14.3 per cent. down to 5.0 per cent. of the total solids present. The latter part of the season of 1898 was quite dry and the water table fell so that some of the wells went dry. The total solids fell with the water table and so did the chlorin, but not proportionately with the total solids; the latter fell from 4.1857 parts per thousand on May 23 to 2.3429 parts on November 7, and the former fell from 0.32400 parts to 0.11071 parts per thousand in the same time. The total solids fell by a little less than one-half their quantity, while the chlorin fell by two-thirds of the amount present when the water table was high, May 23.

§ 57. The chlorin in the water was no indication of the amount of total solids present except within the very wide limits given above, which were different for each individual well; furthermore its quantity varied with the falling of the water table differently from that of the total solids, and increased in a most irregular manner when it rose, especially when the rising of the water table was due to irrigation or to heavy rainfalls. Experiments made by filtering salt solutions through sandstones have shown that they have a considerable power to retain it. Something similar prob-

ably takes place in this case, but the conditions of equilibrium between the salt solution and the soil are changed, perhaps are constantly changing, and the soil retains more of the sodic chlorid as the water table falls, or gives it up as it rises, sometimes in a most irregular fashion. Evaporation from the surface and capillarity undoubtedly influence these changes continuously. This view seems so fully conformable to what we know concerning the deportment of mixed salt solutions when in contact with soil that one is tempted to assert it as a demonstrated fact.

§ 58. Two experiments were made in the hope of gaining definite data relating to it. An excavation was made and a sample taken as soon as the water table was entered, a second sample was taken one foot below this, the water from the first foot being cut off as completely as possible so that the second sample represented water from the soil one foot below the water table ; a third sample was taken at a depth of an additional foot with the same precautions. The respective samples showed the presence of 0.23286, 0.1771 and 0.1171 parts per thousand. Thirteen days later we repeated this experiment, choosing another portion of the plot for our observations. The sample of water taken at the surface of the water table contained 0.2129 parts, and the second one, taken a foot below the surface, showed the presence of 0.1457 parts per thousand. Two other samples were taken at greater depths, but the inflow of water was so great that the results were not so reliable. They showed, however, essentially the same as the second sample.

§ 59. The ratios of the chlorin to the total solids in the two experiments are not concordant and permit no inference whatever to be drawn from them. These facts establish what I have elsewhere stated, that the order of solubility of the different salts and the laws of diffusion are greatly modified by the properties of the soil particles and the relative masses of the soil water and the soil.

§ 60. The effect of irrigation, particularly when sufficient to raise the height of the water table, was to increase the absolute quantity of chlorin in the water, but not proportionately with the other salts. There were differences in the wells in this respect. The ratio of the chlorin to the total solids in well D before irrigation was 1:34, and after irrigation 1:64 ; in wells A and B the changes were in the same direction, but much less ; in the case of well C the change in the ratio, though small, was in the opposite direction. The local conditions, including variations in the soil, seem to influence the amounts of the salts taken into solution and especially the relative quantities of the same. The soil in the vicinity of well C contained, according to analysis, more than twice as much chlorin

as the soils in the vicinity of the other wells. The water soluble in this soil was less than in that about well A, but greater than in that about wells B and D for both the first and second two inches. The percentages of chlorin in the water soluble portions of the soils are not very different, but it is not probable that the salts present in the soils are the same. The whole of the chlorin may be present in the form of ordinary salt in one case and in the form of magnesic or some other chlorid in the other; this seems to be the actual case for we were unable to combine the results of the analyses of these different water soluble portions in the same manner.

§ 61. It was hoped that the amount of the chlorin in the water and its variation from time to time might throw some light upon the movement of the alkali salts in the soil; but these seem so dependent upon local conditions and the character of the soil that no general deductions are justified.

TOTAL SOLIDS.

§ 62. The term total solids is here equivalent to alkali salts in solution in the ground water, and these are not the same as those which form the alkali incrustations, nor are they equal to the water soluble portion of the soil. These are three different mixtures of salts.

§ 63. It has been given as the result of three seasons' observation on this plot that the amount of the total solids varied in different portions, as shown by the fact that the wells differed from one another in this respect, and that there was no relation in the rate or extent of their variations. This is not the case with the composition of the solids held in solution, as shown by more than one hundred complete analyses of the waters of the different wells.

§ 64. I wish to emphasize the statement that the well waters represent the composition of all the water flowing into the well, between the surface of the water table and the bottom of the well, also possibly of water coming from the gravel below the well, for it is certain that however abnormally the salts may diffuse through the solution within the mass of the soil, they are entirely relieved from the influence of the soil particles in the free water accumulating in the wells. These well waters probably represent the average free solution in the soil for a depth represented by the height of the water plane above the bottom of the well, especially if there is no hydrostatic pressure forcing water upward out of a more porous stratum, as might have been the case in some of my wells where they entered the gravel.

§ 65. I have two analyses which, taken with the conditions under which the samples were collected, will fully present this

view. They are of water from wells designated as B and G respectively. Well B was put down in May, 1897, and had been open for a year at the time the sample in question was taken; well G was put down the day the sample was taken. Well B reached the gravel at a depth of 6 feet, while well G was but 4 feet deep, leaving about 2 feet of a difficultly pervious soil between the bottom of the well and the gravel. The analyses of the two samples follow:

TABLE I.—ANALYSIS OF WATER FROM WELL B, MAY 30, 1898.

Analytical Results.	*Per Cent.*	*Grs. Imp. Gal.*	*Combined.*	*Per Cent.*	*Grs. Imp. Gal.*
Silicic Acid	0.541	1.176	Calcic Sulfate	39.704	86.317
Sulfuric Acid	45.871	99.724	Magnesic Sulfate	24.934	54.207
Carbonic Acid	3.318	7.214	Potassic Sulfate	0.370	0.795
Chlorin	6.239	13.563	Sodic Sulfate	10.173	22.166
Sodic Oxid	15.165	32.969	Sodic Clorid	10.292	22.376
Potassic Oxid	0.200	0.435	Sodic Carbonate	7.994	17.378
Calcic Oxid	16.361	35.568	Sodic Silicate	1.099	2.389
Magnesic Oxid	8.304	18.054	Ferric and Alu. Oxids	0.031	0.067
Ferric and Alu. Oxids	0.031	0.067	Manganic Oxid	0.021	0.045
Manganic Oxid	0.021	0.045	Ignition	5.235	11.381
Ignition	5.235	11.381	Sum	99.853	217.073
Sum	101.286	220.196	Excess Sodic Oxid	0.223	0.050
Oxygen Eq. to Chlorin	1.406	3.057	Total	99.876	217.123
Total	99.880	217.139			

Total solids 3.1057 parts per thousand, or 217.4 grains per imperial gallon.

TABLE II.—ANALYSIS OF WATER FROM WELL G, MAY 30, 1898.

Analytical Results.	*Per Cent.*	*Grs Imp. Gal.*	*Combined.*	*Per Cent.*	*Grs. Imp. Gal.*
Silicic Acid	0.665	1.350	Calcic Sulfate	38.430	78.013
Sulfuric Acid	46.504	93.997	Magnesic Sulfate	24.897	50.541
Carbonic Acid	3.580	7.267	Potassic Sulfate	0.212	0.430
Chlorin	6.226	12.639	Sodic Sulfate	12.444	25.261
Sodic Oxid	16.450	33.394	Sodic Chlorid	10.247	20.855
Potassic Oxid	0.115	0.233	Sodic Carbonate	8.632	17.523
Calcic Oxid	15.831	32.137	Sodic Silicate	0.997	2.024
Magnesic Oxid	8.297	16.843	Ferric and Alu. Oxids	0.041	0.083
Ferric and Alu. Oxids	0.041	0.083	Manganic Oxid	0.041	0.083
Manganic Oxid	0.041	0.083	Ignition	4.102	8.327
Ignition	4.102	8.327	Sum	100.073	203.140
Sum	101.652	206.353	Excess Silicic Acid	0.174	0.353
Oxygen Eq. to Chlorin	1.403	2.848	Total	100.244	203.493
Total	100.249	203.505			

Total solids 6.7285 parts per thousand, or 203 grains per imperial gallon.

§ 66. These two analyses differ slightly in the ratios of the respective salts to the total solids, but serve to justify the statement made above that the well waters may be assumed to faithfully represent the composition of the freely circulating waters within the soil to the depth of the well. This is still the case when the water

level changes. The samples, of which analyses have just been given, were taken when the water plane was relatively high and the ground water contained rather more than 28.5714 parts per thousand. The following sample was taken when the water plane had been raised by irrigating the plot, and the total solids present in the water were almost 70 per cent. higher than on May 30th, when the preceding samples were taken. While there are some differences, they are comparatively small, which fact appears most clearly from the percentage composition of the total solids as given by the direct results of the analysis which follows:

TABLE III.—ANALYSIS OF WATER FROM WELL G, JULY 11, 1898.

Analytical Results.	*Per Cent.*	*Grs. Imp. Gal.*	*Combined.*	*Per Cent.*	*Grs. Imp. Gal.*
Silicic Acid	0.337	1.149	Calcic Sulfate	32.866	112.073
Sulfuric Acid.	46.106	157.221	Magnesic Sulfate	27.162	92.622
Carbonic Acid	3.456	11.785	Potassic Sulfate	1.845	6.283
Chlorin	6.317	21.541	Sodic Sulfate	13.897	47.389
Sodic Oxid	17.165	58.533	Sodic Chlorid	10.424	35.546
Potassic Oxid	1.002	3.417	Sodic Carbonate	8.333	28.416
Calcic Oxid	13.539	46.168	Sodic Silicate	0.684	2.332
Magnesic Oxid	9.052	30.867	Ferric and Alu. Oxids	0.070	0.239
Ferric and Alu. Oxids	0.070	0.239	Manganic Oxid	0.060	0.205
Manganic Oxid	0.060	0.205	Ignition	4.352	14.840
Ignition	4.352	14.840			
Sum	101.456	345.965	Sum	99.693	339.945
Oxygen Eq. to Chlorin	1.423	4.852	Excess Sodic Oxid	0.337	1.149
Total	100.033	341.113	Total	100.030	341.094

Total solids 4.7714 parts per thousand, or 341.0 grains per imperial gallon.

§ 67. What has just been said is true of the water of all of the wells throughout the three seasons during which we had them under observation.

§ 68. The salts present, that is constituting the total solids, in the waters are calcic, magnesic, and sodic sulfates with sodic carbonate and chlorid.

§ 69. In the analyses already given, and in those to follow, I have combined the acids and basis in the order adopted in Bulletin 65, believing that this order represents as nearly as any other which might have been adopted, the salts which actually exist in the solution. It is certainly not always correct, but it gives us an easy and uniform method of statement. That it is not correct in every case is clear, for the sodic carbonate appears in the analysis as the normal salt, which when present in the quantities shown by the analyses, ought to react with phenolphthalein, but it does not, and is probably present wholly as the acid carbonate or bicarbonate. The total carbonic acid in the waters as they were taken from the wells was not determined, still there is no doubt but that

the sodic carbonate existed essentially if not wholly as a bicarbonate. Again the calcic sulphate appears in the analysis without any water of crystallization, but it is in no way intended to state that calcic sulphate was actually present as anhydrite. I do not think it possible to tell just how these groups were arranged in the solution, how many of them were free and how many of them combined, but I simply present the probable combinations as an easy and convenient way of expressing our results. The statement of the analysis is so full that further explanation is unnecessary.

§ 70. I find it a common thing, almost a rule, that the analyses show a slight excess of sodic oxid, sometimes, however, the excess is silicic acid. I have also found this to be a common result in the analysis of alkali incrustations. I attributed this excess to the probable presence of organic acids. Examinations for volatile organic acids did not justify the assumption of the excess being due to their presence, for I found them present in very minute quantities. The excess of sodic oxid is usually higher when the loss on ignition is high, than it is when this loss is low. The excess is often very insignificant and within the limits of analytical errors.

§ 71. For the purpose of presenting the general composition of the well waters I will give analyses of samples taken in the month of July, 1897 and 1898, because I think that the samples of this month show less uniformity than those of any other in which regular samples were taken. The following are all of the samples taken from these wells during this month, except some taken immediately after irrigation.

TABLE IV.—ANALYSIS OF WATER FROM WELL A, JULY 5, 1897.

Analytical Results.	*Per Cent.*	*Grs. Imp. Gal.*
Silicic Acid	0.474	1.223
Sulfuric Acid	48.853	126.090
Carbonic Acid	1.997	5.154
Chlorin	5.598	14.448
Sodic Oxid	14.373	37.097
Potassic Oxid	0.321	0.829
Calcic Oxid	14.999	38.712
Magnesic Oxid	9.596	24.767
Ferric and Alu. Oxids	0.177	0.457
Manganic Oxid	0.143	0.369
Ignition	4.410	11.382
Sum	100.941	260.528
Oxygen Eq. to Chlorin	1.261	3.255
Total	99.680	257.273

Combined.	*Per Cent.*	*Grs. Imp. Gal.*
Calcic Sulfate	36.500	94.207
Magnesic Sulfate	28.795	74.320
Potassic Sulfate	0.594	1.533
Sodic Sulfate	13.995	36.121
Sodic Chlorid	9.233	23.830
Sodic Carbonate	4.815	12.428
Sodic Silicate	0.963	2.486
Ferric and Alu. Oxids	0.177	0.457
Manganic Oxid	0.143	0.369
Ignition	4.410	11.382
Sum	99.625	257.133
Excess Sodic Oxid	0.054	0.139
Total	99.679	257.272

Total solids 3.6871 parts per thousand, or 258.1 grains per imperial gallon.
Sample taken six days after irrigation.

TABLE V.—ANALYSIS OF WATER FROM WELL A, JULY 25, 1898.

Analytical Results.	*Per Cent.*	*Grs. Imp. Gal.*
Silicic Acid	0.547	1.456
Sulfuric Acid	45.209	120.346
Carbonic Acid	2.140	5.696
Chlorin	6.475	17.235
Sodic Oxid	14.114	37.572
Potassic Oxid	0.057	0.152
Calcic Oxid	15.397	40.988
Magnesic Oxid	8.515	22.668
Ferric and Alu. Oxids	0.091	0.243
Manganic Oxid	0.037	0.099
Ignition	8.621	22.948
Sum	101.203	269.403
Oxygen Eq. to Chlorin	1.459	3.884
Total	99.744	265.519

Combined.	*Per Cent.*	*Grs. Imp. Gal.*
Calcic Sulfate	37.366	99.468
Magnesic Sulfate	25.568	68.061
Potassic Sulfate	0.106	0.281
Sodic Sulfate	10.903	29.025
Sodic Chlorid	10.681	28.433
Sodic Carbonate	5.155	13.721
Sodic Silicate	1.111	2.958
Ferric and Alu. Oxids	0.091	0.243
Manganic Oxid	0.037	0.099
Ignition	8.621	22.948
Sum	99 639	265.237
Excess Sodic Oxid	0.101	0.268
Total	99.740	265.505

Total solids 3.8028 parts per thousand, or 266.2 grains per imperial gallon.

TABLE VI.—ANALYSIS OF WATER FROM WELL B, JULY 5, 1897.

Analytical Results.	*Per Cent.*	*Grs. Imp. Gal.*
Silicic Acid	0.646	1.406
Sulfuric Acid	46.912	102.081
Carbonic Acid	2 166	4.713
Chlorin	5.795	12.610
Sodic Oxid	16.679	36.294
Potassic Oxid	0.531	1.155
Calcic Oxid	14.158	30.808
Magnesic Oxid	8.299	18.059
Ferric and Alu. Oxids	0.141	0.307
Manganic Oxid	0.070	0.152
Ignition	5.909	12 858
Sum	101.306	220.443
Oxygen Eq. to Chlorin	1.306	2.842
Total	100.000	217.601

Combined.	*Per Cent.*	*Grs. Imp. Gal.*
Calcic Sulfate	34.359	74.765
Magnesic Sulfate	24.903	54.189
Potassic Sulfate	0.982	2.137
Sodic Sulfate	17.149	37.316
Sodic Chlorid	9.558	20.798
Sodic Carbonate	5.223	11.365
Sodic Silicate	1.312	2.855
Ferric and Alu. Oxids	0.141	0.307
Manganic Oxid	0.070	0.152
Ignition	5.909	12.858
Sum	99.606	216.742
Excess Sodic Oxid	0.394	0.856
Total	100.000	217.598

Total solids 3.1085 parts per thousand, or 217.6 grains per imperial gallon.
Sample taken six days after irrigation.

TABLE VII. ANALYSIS OF WATER FROM WELL B, JULY 25, 1898.

Analytical Results.	*Per Cent.*	*Grs. Imp. Gal.*
Silicic Acid	0.619	1.750
Sulfuric Acid	45.837	129.581
Carbonic Acid	2 561	7.240
Chlorin	6 413	18.129
Sodic Oxid	17.849	50.459
Potassic Oxid	0.101	0.286
Calcic Oxid	14.146	39.981
Magnesic Oxid	7.712	21.802
Ferric and Alu. Oxids	0.030	0.085
Manganic Oxid	0.030	0.085
Ignition	6.117	17.293
Sum	101.415	286.691
Oxygen Eq. to Chlorin	1.445	4.085
Total	99 970	282.606

Combined.	*Per Cent.*	*Grs. Imp. Gal.*
Calcic Sulfate	34.339	97.076
Magnesic Sulfate	23 141	65.420
Potassic Sulfate	0.186	0.526
Sodic Sulfate	17.988	50.852
Sodic Chlorid	10.583	29.918
Sodic Carbonate	6.175	17.457
Sodic Silicate	1.258	3.556
Ferric and Alu. Oxids	0.030	0.085
Manganic Oxid	0.030	0.085
Ignition	6.117	17.293
Sum	99.847	282.268
Excess Sodic Oxid	0.121	0.342
Total	99.968	282.610

Total solids 4.0385 parts per thousand, or 282.7 grains per imperial gallon.

TABLE VIII.—ANALYSIS OF WATER FROM WELL C, JULY 5, 1897.

Analytical Results.	*Per Cent.*	*Grs. Imp. Gal.*	*Combined.*	*Per Cent.*	*Grs. Imp. Gal.*
Silicic Acid..........	0.408	0.816	Calcic Sulfate........	40.901	81.802
Sulfuric Acid........	50.288	100.576	Magnesic Sulfate.....	22.874	45.748
Carbonic Acid........	2.550	5.100	Potassic Sulfate......	0.631	1.262
Chlorin	3.294	6.588	Sodic Sulfate.........	19.003	38.006
Sodic Oxid..........	15.651	31.302	Sodic Chlorid........	5.433	10.866
Potassic Oxid........	0.341	0.682	Sodic Carbonate......	6.149	12.298
Calcic Oxid..........	16.854	33.708	Sodic Silicate........	0.829	1.658
Magnesic Oxid.......	7.623	15.246	Ferric and Alu. Oxids	0.260	0.520
Ferric and Alu. Oxids	0.260	0.520	Manganic Oxid.......	0.137	0.274
Manganic Oxid.......	0.137	0.274	Ignition..............	3.661	7.322
Ignition..............	3.661	7.322	Sum...... ...	99.878	199.756
Sum...........	101.067	202.134	Excess Sodic Oxid....	0.447	0.894
Oxygen Eq. to Chlorin	0.741	1.482	Total..........	100.325	200.650
Total..........	100.326	200.652			

Total solids 2.5714 parts per thousand, or 200.0 grains per imperial gallon.
Sample taken six days after irrigation.

TABLE IX.—ANALYSIS OF WATER FROM WELL C, JULY 25, 1898.

Analytical Results.	*Per Cent.*	*Grs. Imp. Gal.*	*Combined.*	*Per Cent.*	*Grs. Imp. Gal.*
Silicic Acid..........	0.609	1.121	Calcic Sulfate........	30.752	56.615
Sulfuric Acid.........	46.151	84.965	Magnesic Sulfate.....	24.622	45.329
Carbonic Acid........	3.911	7.201	Potassic Sulfate......	0.029	0.053
Chlorin...............	4.770	8.781	Sodic Sulfate.........	20.666	38.047
Sodic Oxid...........	19.651	36.177	Sodic Chlorid........	7.869	14.486
Potassic Oxid........	0.015	0.028	Sodic Carbonate.....	9.423	17.348
Calcic Oxid..........	12.672	23.329	Sodic Silicate........	1.237	2.278
Magnesic Oxid..	8.200	15.097	Ferric and Alu. Oxids	0.045	0.082
Ferric and Alu. Oxids	0.045	0.082	Manganic Oxid.......	0.040	0.073
Manganic Oxid.......	0.040	0.073	Ignition..............	4.938	9.090
Ignition..............	4.938	9.090	Sum...........	99.621	183.401
Sum...........	101.002	185.944	Excess Sodic Oxid....	0.304	0.560
Oxygen Eq. to Chlorin	1.075	1.979	Total..........	99.925	183.961
Total..........	99.927	183.965			

Total solids 2.6300 parts per thousand, or 184.1 grains per imperial gallon.

TABLE X.—ANALYSIS OF WATER FROM WELL D, JULY 5, 1897.

Analytical Results.	*Per Cent.*	*Grs. Imp. Gal.*	*Combined.*	*Per Cent.*	*Grs. Imp. Gal.*
Silicate Acid.........	0.639	1.040	Calcic Sulfate........	35.477	57.712
Sulfuric Acid........	45.490	74.012	Magnesic Sulfate.....	19.057	31.006
Carbonic Acid........	2.351	3.825	Potassic Sulfate......	0.353	0.574
Chlorin....	5.765	9.380	Sodic Sulfate.........	20.893	33.993
Sodic Oxid...........	18.578	30.226	Sodic Chlorid	9.509	15.471
Potassic Oxid.........	0.191	0.311	Sodic Carbonate......	5.669	9.223
Calcic Oxid..........	14.619	23.785	Sodic Silicate.........	1.298	2.112
Magnesic Oxid........	6.351	10.333	Ferric and Alu. Oxids	0.639	1.040
Ferric and Alu. Oxids	0.639	1.040	Manganic Oxid.......	0.067	0.109
Manganic Oxid.......	0.067	0.109	Ignition..............	6.579	10.704
Ignition.............	6.579	10.704	Sum...........	99.541	161.953
Sum...........	101.269	164.765	Excess Sodic Oxid....	0.429	0.698
Oxygen Eq. to Chlorin	1.299	2.113	Total..........	99.970	162.651
Total..........	99.970	162.652			

Totol solids 2.3242 parts per thousand, or 162.7 grains per imperial gallon.
Sample taken six days after irrigation.

TABLE XI.—ANALYSIS OF WATER FROM WELL D, JULY 19, 1897.

Analytical Results.	Per Cent.	Grs. Imp. Gal.	Combined.	Per Cent.	Grs. Imp. Gal.
Silicic Acid..........	0.539	1.103	Calcic Sulfate........	36.851	75.435
Sulfuric Acid.........	45.095	92.309	Magnesic Sulfate.....	20.789	42.555
Carbonic Acid........	2.695	5.517	Potassic Sulfate......	0.638	1.306
Chlorin...............	6.271	12.837	Sodic Sulfate.........	16.472	33.718
Sodic Oxid...........	17.089	34.981	Sodic Chlorid........	10.343	21.172
Potassic Oxid........	0.345	0.706	Sodic Carbonate......	6.498	13.301
Calcic Oxid...........	15 185	31.084	Sodic Silicate.........	1.095	2.241
Magnesic Oxid........	6.928	14.182	Ferric and Alu. Oxids	0.207	0.424
Ferric and Alu. Oxids	0.207	0.424	Manganic Oxid.......	0.061	0.125
Manganic Oxid.......	0.061	0.125	Ignition..............	6.490	13.285
Ignition..............	6.490	13 285	Sum...........	99.444	203.562
Sum...........	100.995	206.553	Excess Sodic Oxid....	0.047	0.096
Oxygen Eq. to Chlorin	1.413	2 892	Total..........	99.491	203.658
Total..........	99.492	203.661			

Total solids 2.9242 parts per thousand, or 204.7 grains per imperial gallon.

TABLE XII.—ANALYSIS OF WATER FROM WELL D, JULY 25, 1898.

Analytical Results.	Per Cent.	Grs. Imp. Gal.	Combined.	Per Cent.	Grs. Imp. Gal.
Silicic Acid..........	0.520	1.203	Calcic Sulfate........	35.466	82.033
Sulfuric Acid.........	46.633	107.862	Magnesic Sulfate.....	23.883	55.241
Carbonic Acid........	3.217	7.441	Potassic Sulfate......	0.178	0.412
Chlorin..............	3.067	7.094	Sodic Sulfate.........	17.353	40.137
Sodic Oxid...........	15.448	35.731	Sodic Chlorid........	5.059	11.701
Potassic Oxid........	0.096	0.222	Sodic Carbonate.....	7.757	17.942
Calcic Oxid...........	14.610	33.793	Sodic Silicate........	1.056	2.443
Magnesic Oxid........	7.959	18.409	Ferric and Alu. Oxids	0.087	0.201
Ferric and Alu. Oxids	0.087	0.201	Manganic Oxid.......	0.087	0.201
Manganic Oxid.......	0.087	0.201	Ignition..............	8.821	20.404
Ignition..............	8.821	20.404	Sum	99.747	230.715
Sum...........	100.545	232.561	Excess Sodic Oxid....	0.107	0.248
Oxygen Eq. to Chlorin	0.691	1.598	Total..........	99.854	230.963
Total..........	99.854	230.963			

Total solids 3.30429 parts per thousand, or 231.3 grains per imperial gallon.

§ 72. These analyses present the highest limit of the sulfates not only for this month but for the whole time that the plot was under observation. The sample from well C, taken July 5, 1897, six days after irrigation, shows the presence of 50.29 per cent. sulfuric acid, SO_3, which is nearly 1.5 per cent. higher than the next highest one given and is the highest, with one exception, in the whole series representing the three seasons' work. That the average percentage of sulfuric acid for all of the analyses made of these well waters is lower than that shown by these for the month of July may be inferred from the fact that there are only 8 in the 105 analyses made showing 48 per cent. or more of this constituent.

§ 73. The analyses given show almost as great a range in the quantity of chlorids present as the whole number of samples taken. There are only a few exceptional samples which show either higher or lower figures for the chlorids than those given.

§ 74. These samples also serve to represent the general composition of the total solids present in this class of ground waters. As a matter of course it is not intended that one shall infer from this statement that the alkaline ground waters occurring in different parts of the state are so rich in total solids or that the different salts are present in the same proportions, but that the ground waters in alkalied sections are of this general type. I have not yet found any ground water materially richer in sodic chloride (common salt) or sodic carbonate. It is true that some surface well waters that have come to hand for analysis, have shown relatively much larger amounts of carbonates, while the total solids were materially less in quantity. These waters were from wells sunk for the purpose of obtaining potable water, or water for use in boilers, and I assume that the samples represented the best procurable quality of such waters.

§ 75. The following analysis of a water struck at a depth of 28 feet and occurring in a two-foot stratum of sand, will serve for comparison with the analyses of ground waters already given. This sample of water was sent to us from Rockyford, in the Arkansas Valley:

TABLE XIII.—ANALYSIS OF WATER FROM ROCKYFORD, JULY 26, 1900.

Analytical Results.	*Per Cent.*	*Grs. Imp. Gal.*	*Combined.*	*Per Cent.*	*Grs. Imp. Gal.*
Silicic Acid	0.141	0.880	Calcic Sulfate	15.206	94.870
Sulfuric Acid	45.136	281.603	Magnesic Sulfate	29.059	181.299
Carbonic Acid	3.989	24.887	Potassic Sulfate	Trace	Trace
Chlorin	3.772	23.533	Sodic Sulfate	29.865	186.328
Sodic Oxid	22.277	138.986	Sodic Chlorid	6.224	38.832
Potassic Oxid	Trace	Trace	Sodic Carbonate	9.619	60.013
Calcic Oxid	6.264	39.081	Sodic Silicate	0.286	1.784
Magnesic Oxid	9.684	60.418	Ferric and Alu. Oxids	0.010	0.062
Ferric and Alu. Oxids	0.010	0.062	Manganic Oxid	0.040	0.250
Manganic Oxid	0.040	0.250	Ignition	9.233	57.605
Ignition	9.233	57.605	Sum	99.542	621.043
Sum	100.546	627.307	Excess Sodic Oxid	0.152	0.948
Oxygen Eq. to Chlorin	0.850	5.303	Total	99.694	621.991
Total	99.696	622.004			

Total solids 8.9129 parts per thousand, or 623.9 grains per imperial gallon.

§ 76. A sample of ground water from this locality, Rockyford, taken under my own directions, but at a depth of 12 feet, differed from the above in the relative amounts of calcic and magnesic sulfates, but the quantities of sodic sulfate and chlorid were nearly the same.

§ 77. There is, as I have previously intimated, probably a difference between samples taken as soon as the water plane has been entered and after the well has been emptied several times by continued pumping or bailing; there is, besides, in shallow wells

at least, a difference due to the conditions which prevailed immediately prior to the time of taking the sample.

§ 78. Outside of these general features but little is shown by the composition of the ground waters as collected in the wells. The changes observed are not so great as were looked for, and when the variations due to changes in conditions immediately before the taking of the samples have been allowed for, the uniformity throughout the period of observation, a period of nearly three years, leaves but little doubt of the correctness of the conclusion that, while the total solids may vary in their quantity and in composition, too, within narrow limits, they remain in all essential respects the same.

THE GROUND WATERS DIFFERENT FROM ALKALIES—ALSO FROM THE DRAIN WATERS.

§ 79. The total solids, obtained by evaporating the ground waters, represent a different mixture of salts than that which is obtained by continued treatment of the soil with frequently renewed portions of distilled water, until it is so thoroughly exhausted that no sulfuric acid can be found in the solution after standing in contact with the soil for not less than 12 hours. Attention was called to this fact in Bulletin 65, where some analyses of the water-soluble portions of this soil are given, together with their most characteristic features.

§ 80. In the following comparison we shall not make any attempt to assign causes for the differences which are undoubtedly to be found in the complex reactions taking place between the different salts or their ions within the mass of the soil, and also to the formation of salts de novo, due to the action of water as such, and of solutions upon the rock particles in the soil. In Bulletin 65 the suggested explanation was confined almost wholly to the latter phase of the question because it is the simplest feature of it and conveys a sufficiently extensive view of the subject without introducing any of the more difficult questions involved in the theory of solutions. For a fuller and sufficient explanation of the facts recourse must be had to this branch of the subject, but I shall content myself with as clear a statement of the facts as I may be able to make.

§ 81. The samples which I have chosen are a sample of water from well C, the water soluble portions from two samples of soil C and a representative alkali incrustation. The designation well C and soil C is equivalent to stating that the sample of soil was taken as near to well C as we deemed advisable, which in this case was within 11 feet.

§ 82. It is difficult to present this subject without reproducing all of the analyses representing the different sections of the plot, for they differ so much in character that one is not really representative of the plot. The suggested difficulties are still greater than the simple lack of representativeness, for it suggests that the chemical reactions taking place within very limited areas of soil may be but partially or not at all comparable. This difference is made strikingly evident by the difference in the salts present in the water-soluble portions of the first and second two inches of these soils. Whether I have adopted the proper order of combination or not does not matter. I have adopted the same method of interpretation in all cases, which in itself may be an error, still it brings out several important and scarcely questionable differences.

§ 83. I shall select section C for my present purpose, because it is less favorable to my presentation of this subject than B or D, and rather more favorable than section A. The reader who wishes to compare the results obtained for the other sections can find the analyses of the water-soluble portions of the soil in Bulletin 65, pages 36, 37 and 38.

§ 84. The samples of soil were taken, one in May and the other in June. The sample of water was taken in June. It would have been better for the present purpose had they been taken at the same time as well as from the same place, but I have chosen these from the samples taken, as being the nearest together in the point of time of collecting.

§ 85. The alkali which I use in this case was also collected in June, but nearer to well A than to well C. This, however, does not detract from its value for the purpose of comparison, for other samples show that the differences in the alkali incrustations of this plot do not lie in the salts of which they are composed, but in their relative quantities. I have a sample taken nearer to well C, but it was taken in January during freezing weather, which, owing to the deportment of sodic sulfate at low temperatures, might make it less comparable than the one chosen.

The arrangement of the analyses is evident.

TABLE XIV.—ANALYSIS OF ALKALI, INCRUSTATION.

Analytical Results.	*Per Cent.*
Silicic Acid	0.491
Sulfuric Acid	52.403
Carbonic Acid	0.730
Chlorin	2 004
Sodic Oxid	26.797
Potassic Oxid	0.048
Calcic Oxid	3.050
Magnesic Oxid	8.951
Ferric and Alu. Oxids	0.030
Manganic Oxid	0.129
Ignition	5 384
Sum	100.017
Oxygen Eq. to Chlorin	0.451
Total	99.566

Combined.	*Per Cent.*
Calcic Sulfate	7.404
Magnesic Sulfate	26.859
Potassic Sulfate	0.088
Sodic Sulfate	53.450
Sodic Chlorid	3.307
Sodic Carbonate	1.760
Sodic Silicate	0.997
Ferric and Alu. Oxids	0.030
Manganic Oxid	0.129
Ignition	5.384
Sum	99 408
Excess Sodic Oxid	0.157
Total	99.565

TABLE XV.—ANALYSIS WATER-SOLUBLE, SOIL C, FIRST TWO INCHES.

Analytical Results.	*Per Cent.*
Silicic Acid	1.084
Sulfuric Acid	48.826
Phosphoric Acid	None
Carbonic Acid	0 385
Chlorin	4.321
Potassic Oxid	1 338
Sodic Oxid	10.190
Calcic Oxid	17.826
Magnesic Oxid	8 080
Ferric and Alu. Oxids	——
Manganic Oxid	0 342
Ignition	8.281
Sum	100.673
Oxygen Equivalent to Chlorin	0 973
Total	99.700

Combined.	*Per Cent.*
Calcic Sulfate	43.260
Magnesic Sulfate	24 260
Potassic Sulfate	2.475
Sodic Sulfate	10.789
Sodic Chlorid	7.128
Sodic Carbonate	0 928
Sodic Silicate	2 202
Ferric and Alu. Oxids	——
Manganic Oxid	0.342
Ignition	8.281
Sum	99.665
Excess Sodic Oxid	0.031
Total	99.696

The percentage of water-soluble equalled 2.0544.

TABLE XVI.—ANALYSIS WATER-SOL., SOIL C, SECOND TWO INCHES.

Analytical Results.	*Per Cent.*
Silicic Acid	9.095
Sulfuric Acid	34.832
Phosphoric Acid	0.522
Carbonic Acid	5.558
Chlorin	2.663
Potassic Oxid	3.252
Sodic Oxid	8.778
Calcic Oxid	20.981
Magnesic Oxid	7.131
Ferric and Alu. Oxids	0.878
Manganic Oxid	0.245
Ignition	6.996
Sum	100.951
Oxygen Equivalent to Chlorin	0.600
Total	100.351

Combined	*Per Cent.*
Calcic Sulfate	50.917
Magnesic Sulfate	3.197
Potassic Sulfate	6.016
Magnesic Phosphate	0.963
Magnesic Chlorid	3.565
Magnesic Carbonate	8.646
Sodic Carbonate	2.490
Sodic Silicate	14.418
Ferric and Alu. Oxids	0.898
Manganic Oxid	0.245
Ignition	6.996
Sum	98.351
Excess of Silicic Acid	1.998
Total	100.349

The percentage of water-soluble equalled 0.813.

TABLE XVII. ANALYSIS OF WATER FROM WELL C, JUNE 13, 1898.

Analytical Results.	*Per Cent.*	*Combined.*	*Per Cent.*
Silicic Acid	0 656	Calcic Sulfate	35 054
Sulfuric Acid	44.875	Magnesic Sulfate	21.520
Carbonic Acid	3 517	Potassic Sulfate	0.107
Chlorin	5.144	Sodic Sulfate	17.517
Sodic Oxid	18.108	Sodic Chlorid	8.487
Potassic Oxid	0.058	Sodic Carbonate	8.474
Calcic Oxid	14.445	Sodic Silicate	1.333
Magnesic Oxid	7.167	Ferric and Alu. Oxids	0.026
Ferric and Alu. Oxids	0.026	Manganic Oxid	0.041
Manganic Oxid	0 041	Ignition	6.911
Ignition	6.911	Sum	99.470
Sum	100.948	Excess Sodic Oxid	0.316
Oxygen Equivalent to Chlorin	1 159	Total	99.786
Total	99.789		

§ 86. The alkali or incrustation which collected on the surface of the soil is essentially a mixture of sodic and magnesic sulfates in the ratio of two to one. These two salts make up 80 per cent. of the whole mass. Calcic sulfate is subordinate in quantity, with sodic chlorid and carbonate still more so.

§ 87. In the first two inches of the soil we find that the soluble salts consist largely of calcic, magnesic and sodic sulfates, which together form 78.3 per cent. of them, with the calcic sulfate predominant. In the second two inches the calcic sulfate constitutes almost 51 per cent. of the water-soluble portion of the soil, with magnesic sulfate subordinate and sodic sulfate absent. On the other hand, sodic silicate, which is very subordinate in the alkali and ground water, is here next in quantity to the calcic sulfate, and the potassic sulfate, which is present in scarcely more than traces in the alkali given, makes about 1-16 of the water-soluble portion of the second two inches of the soil. The potassic salts in the alkali incrustations which I have examined and which were formed as efflorescences, are sometimes higher than in the one given, amounting in some cases to about 1 per cent. In an alkali from South Park, Colo., the potassic salts were a little over 8 per cent., but the conditions are wholly different from those prevailing in our plot.

§ 88. The variety of salts in the water-soluble portion of the soils seems to be greater and the relative quantities of the subordinate ones are much more nearly equal than in the alkali or the water. Reference to the analyses of the other water-soluble portions of the soils will show a tendency in this direction in the first two, but it is more marked in the second two inches of soil. In no case do we have an increase in the amount of the more soluble sodic and magnesic sulfates in the second two inches of soil, while that of the less soluble calcic sulfate is quite marked.

§ 89. The analyses of the waters from the wells agree with the one given in showing that the total solids in the ground water contain more calcic sulfate than the incrustations, but much less than the water-soluble portions of the soils, whether it is of the first or second two inches. The results of the analyses of other samples also agree relative to the magnesic sulfate, viz.: that there is almost as much in the water residues as there is in the incrustation or in the first two inches of the soil C, and more than in any of the other seven water-soluble portions examined.

§ 90. The most marked difference is shown in the case of the sodic sulfate, which makes up 53 per cent. of the alkali incrustation, 17 per cent. of the solids dissolved in the ground water, 10 per cent. of the water-soluble in the first two inches of the soil, and is absent in the second two inches. The analyses given above do not stand alone in indicating this difference, but many analyses, all that we have made of the ground waters and three other soil samples, indicate this to be a fact. Sodic sulfate is always a constituent of the total solids in the ground waters, varying in quantity from less than 5 per cent. to 23 per cent. I may state here, as an unlooked-for result, that this salt almost disappears from the drain water coming from this area.

§ 91. The appearance of these two salts, sodic and magnesic sulfates, in the incrustations, seems very reasonable if the suggestion made in Bulletin 65, that the incrustation is formed by an approximate separation of these efflorescent salts from the more permanent ones, especially calcic sulfate, at the contact of the water surface with the air, is correct. The suggestion of the formation of a double magnesic sodic sulfate lies near at hand in this case, but whatever the case may be, we are not justified by the ratio of the magnesic salt to the sodic salt in assuming its formation; besides there is no urgent need of it, as the deportment of these two sulfates toward the air surface is sufficiently different from that of calcic sulfate to permit of the separation as observed. The formation of these incrustations is very different from the simple evaporation of a solution of different salts to dryness, for these efflorescent salts are removed from the solution and its former status is changed.

§ 92. Why the sodic sulfate forms so small a percentage of the water-soluble portion of the soil is not easily explained. That it should sometimes be found in the upper portions of the soil in large quantities is to be expected, even if as a rule it were present in small quantities only or entirely absent, for the tendency is to a separation of it on the surface, whence it may be carried back into the soil by rain or abundant atmospheric moisture, being retained within the surface layers of the soil in which it may form a large percentage of the water-soluble portion. We have one instance in

which it forms 27 per cent. of it. But, remembering that this sulfate does not pass into the drain waters, while it usually exceeds 10 per cent., often rises above 17 and sometimes reaches 23 per cent. of the salts in the ground water, it seems strange that the water-soluble portion of the soil should so frequently give good reason for supposing it to be absent. I do not know any facts nor have I seen any statement of established or probable changes which will account for these facts as observed.

§ 93. The magnesic and sodic sulfates are both present in the ground water, or their ions are, and constitute the efflorescent salts passing out of solution at the surface of the soil, or where the surface of the solution comes in contact with the air. Evaporation is proceeding at this surface and the capillary movement of the ground water is rapid and free. for when the condition of the soil is such that we can sufficiently impede the capillary rise of the water, we prevent the formation of such incrustations. The result may be roughly presented as the movement of a free solution through the interstices of particles which are themselves not free to move, but capable of being modified in regard to their composition either by exchange or by attracting to themselves and retaining other salts. These processes may be subject to the greatest variety of modifications, so that they are not exclusive or constant, and seldom perfected, but vary from point to point within the soil.

§ 94. It has been accepted for a long time that soils as a rule have a high power of retaining potassic salts and but a very feeble one of retaining soda salts. If this were wholly correct, we should expect to find the drain waters from such areas as the one forming the subject of this study loaded with soda salts, at least to the same extent, if not to a much greater one, than the ground waters. But we do not find this to be the case, and the conditions are such that it is not probable that the difference is due to the dilution of the drain waters from this area by water from other sources.

§ 95. Under the subject of the total solids in the ground water, I stated the result of experiment to be an indication that they decreased with depth, that the first foot of water after entering the water plane was richer in total solids than the second, and so on. At first I did not believe this. An instance in point was well D, which on September 20th showed the presence of 3.4071 parts total solids per thousand. A temporary well opened on this date 40 feet south of well D, the surface contour and the character of the soil being the same but the sample of water being obtained at a greater depth, probably two feet deeper, showed only 2.18713 parts total solids per thousand. The residue from the water of well D showed the presence of 16.87 per cent. of sodic sulfate, while that from the newly opened one showed 14 per cent., a difference of

nearly 3 per cent. in this respect. In this case we almost certainly had an admixture of water from points above that at which we endeavored to collect the water, for with our appliances we could not prevent it. The drain waters, in which we have a better separation of the waters, show a still greater difference, both in the amount of the total solids and in the percentage of the sodic sulfate. We are justified in extending our statement that the ground water, in so far as it is a solution of salts, differs from the alkalis which effloresce, from the solution obtained by exhausting the soil with distilled water as previously described, and also from the drain water flowing from under the area.

LITHIA IN THE GROUND WATER.

§ 96. Reference has been made in a preceding bulletin to the failure of an attempt to determine the lateral movement of this salt through the soil, or the rate and direction of the flow of the ground water. The detection of lithia in the samples of water tested to ascertain with certainty that my experiment was actually a failure, led me to test a considerable number of samples of the ground water and also samples of drain water to ascertain whether its presence was accidental or whether its occurrence was general and constant. The result was that its presence was established qualitatively in every sample tested, and these represented samples taken during a period extending over more than two years. The quantity present was as a matter of course not large, but sufficient to be readily detected by the aid of the spectroscope, and in some of the samples sufficient for quantitative determination without great trouble. This element seems to be present in all of the water in this basin. Its presence was detected in the ash of beets grown upon this plot, and also in the ash of their leaves. This is peculiar for I have tested a number of ashes of alfalfa; some of it grown within this same swale and have never succeeded in detecting it.

NITRATES IN THE GROUND WATER.

§ 97. The results of the only determinations of the nitrates in the soil are given in Bulletin 65, page 45. The variation in the amount present in the different portions of the plot and also in the first and second two inches of soil is very considerable. The determinations are entirely conclusive that the conditions obtaining do not prevent the formation of nitric acid, and further, that its distribution in depth as well as from place to place throughout the plot is very uneven. The minimum quantity of nitric acid in a million parts of the air dried soil of the first two inches was 32 and the maximum 162; of the second two inches the minimum was a trace and the maximum was 9 parts. In A, the section of the plot where the conditions were most unfavorable to cultivation, there was 32

parts per million; in B, where the conditions of cultivation were good, but where we had trouble to obtain a good stand of plants and the ground water was generally the most heavily laden with total solids, the nitric acid was the highest, reaching 162 parts per million; in C, a section which is quite wet and yields incrustations, but in a less degree than A, the nitric acid falls to 55 parts per million, but it again rises to 86 parts per million in D, which section is in good condition and whose surface is always from 3.5 to 6 feet above the water table.

§ 98. We do not find nitric acid abundant in any portion of the plot in the second two inches, it being present in the sample from section A as a trace only, but it increases as the ground rises to the westward until it reaches a maximum of 9.3 parts per million in D.

§ 99. At the close of the season of 1897, 23 days before our crop was harvested, the ground water from the wells showed a range of total solids from 2561 to 3986 parts per million, while the nitric acid ranged from 4 to 7.8 parts. A sample of water taken from a newly made opening penetrating the gravel and quite near to the Town Ditch, an irrigating ditch, showed the presence of 2187 parts total solids and 11.34 parts of nitric acid per million. The water plane was low at the time these samples were taken.

§ 100. On the 16th of May, 1898, the level of the ground water was not especially high, but the total solids were exceptionally so, and the nitric acid in the waters of wells A and C was unprecedentedly high, 41 and 68 parts per million respectively, but this was not so in the case of wells B and D, which carried 5.0 and 2.7 parts respectively. From this date, May 16th, the nitric acid fell continuously till June 6th, when owing to a rainfall there was a change in the soil conditions, followed by an increase of nitric acid in wells A and D and by a decrease of it in wells B and C. From this time, June 6th, till July 14th, the water table gradually fell and so did the quantity of nitric acid present; the surface of the ground having become somewhat dry in the meantime. The plot received an irrigation on July 14th and the samples of water taken on the following day showed an increase in the amount of nitric acid present; but this increase was not uniform in the different wells. The water plane was raised according to the position of the wells, and the amount of water we were able to bring on the surrounding section, which varied, as we had only a scanty supply of water at our disposal. The effects of this irrigation upon the total solids held by the waters was as marked as any that I have had the opportunity of observing. Wells A, B and C rose from 28.0000, 29.2856 and 16.1429 parts per thousand on the 8th to 58.8571, 44.8571, and 58.1429 parts per thousand

on the 11th, while well D, probably due to accidental inflow of water from the surface, fell. The nitric acid rose in the meantime by 7 parts per million in A, 13 parts in B, 18 parts in C, and 1 part in D. The largest increase, however, was observed in a well sunk in an adjoining plot which had been manured and which chanced to receive an irrigation at this time. This well showed 3.59 parts of nitric acid per million on June 27th and 475.63 parts on July 9th. The water table was raised, in this case, almost to the surface.

§ 101. The duration of the effects of this irrigation upon the amount of nitric acid in the water was quite different in the different wells. The greatest increase in my plot was shown in the case of well C, which, throughout the season, proved to be the richest in nitric acid of any of the four wells here considered, and also of all the wells on my plot of ground. The water of this well carried on the 8th of July 2.69 parts nitric acid per million ; this rose to 21.18 parts just after the irrigation and fell to 2.51 parts by August 1st. The nitric acid in well B did not increase to the same extent as in well C, but it fell a little more slowly, and on this date, August 1st, showed more than either of the other three wells. The quantities for all the wells ranged from 1.8 to 6.1 parts per million.

§ 102. The rate of decrease was quite rapid at first, and while it gradually grew slower, it was quite abrupt at the end. The well alluded to as being in an adjacent plot may serve as an illustration of both the rapidity of the rise and the rate of decrease. On July 4th, before irrigation, and with a low water level, it carried only a trace; on the 9th, after irrigation, and with the water plane near the surface, it carried 475.63 parts per million. In the next two days this fell to 242.0 parts, in the succeeding seven days it fell to 89.74, in seven days more to 35.89 parts, and in seven days more to what may be expressed as within the range of its constant content. This well behaved unlike the others, for while mine showed a temporary increase in nitric acid about August 8th, this one continued to decrease until there was less than 1 part of nitric acid per million.

§ 103. As a rule the nitric acid was lower when the water plane was low, but there were variations which showed no relation to either the height of the water level or to the amount of the total solids present; for instance, the nitric acid in the water of well C on August 1st was 2.5 parts per million, on the 8th 8.4 parts, on the 22d 2.7 parts; the total solids on the 1st were 2.0143 parts per thousand, on the 8th 1.9143 parts, and on the 22d 1.8000 parts. The height of the water table on the 1st was 7.75 feet, on the 8th 7.67 feet, and on the 22d 7.15 feet above the reference plane. The

increase on the 8th was probably due to a rainfall which took place on the 5th and 6th and amounted to 0.78 of an inch. There were also slighter rainfalls on the 1st, 2d, 16th and 17th, but the total of these amounted to only .12 of an inch, the heaviest one was only .07 of an inch, too small an amount to produce an observable influence. The comparatively small rainfall of .78 of an inch seems to have been the cause of the increase of the nitric acid in the ground water, for the increase in the four wells was simultaneous, though quite unequal; the greatest increase being 6 parts per million, the least 1 part per million. The effect of this rainfall was not great enough to show in well E, as the nitric acid was falling at a rapid rate and our samples were not taken often enough to show small variations in the rate of falling.

§ 104. There was a slight change of the water table between the 6th and the 8th, amounting to a few hundredths, the greatest being 0.08 of a foot. The actual distance of the water table below the surface at this time was from 3.0 to 5.2 feet. Under these conditions there can scarcely be a thought of the nitric acid, nitrates, having been added to the ground waters by its direct washing downward through the soil. The wells in which the water was the deepest below the surface showed the greatest increase. This is what we would expect if the rain water simply flowed through the soil, carrying the nitric acid or its equivalent nitrates down with it. This amount of rainfall, 0.78 of an inch, is, however, insufficient to wet this depth of soil. As the surface of this soil was in an almost air dry condition at the time of the rainfall, it was probably not wet to a depth greater than two inches, which is a liberal estimate, but if we put the depth to which the rain water penetrated at four times this estimate, it would not account for the rise in the water table, nor for the washing downward of the nitric acid to a depth of a little more than 5 feet. I think that the oscillation in the water plane and the increase in the nitric acid in the water were both due to the effect of the rainfall upon the capillary conditions of the soil; the nitric acid, more explicitly the nitrates, exhibiting a downward capillary movement.

§ 105. A sample of water taken from well A on December 7, 1898, showed only a trace of nitric acid. This determination was repeated to assure myself that no mistake had been made, but the results were the same, corroborating the first determination. This was the fourth instance that we had met with in which there was only a trace of nitric acid present in the water. These four instances were met with when the water plane was low, but not when it was at its lowest.

§ 106. Well A was located in a portion of the plot where the incrustations formed most abundantly, where the mechanical con-

ditions of the soil were most unfavorable and where the water plane was the nearest to the surface at all times. This last fact may have effected a more regular removal of the nitric acid as it was formed than in the other cases. Whether this is the explanation or not, the water from this well showed uniformly as much nitric acid as that of any of the other wells, though the first two inches of the soil was lower in nitric acid than the corresponding samples from the other sections, but irrigation did not increase the nitric acid in the water of this well as it did in some of the others.

§ 107. Well C is located in the next most unfavorable section and the water level is in round figures 1 foot further below the surface than in well A. The nitric acid varied greatly in the water from this well, and its amount was immediately and greatly affected by irrigation or rainfall, even a light rainfall being followed by a marked increase in the amount of nitric acid.

§ 108. I have said nothing about well G, a shallow well near well A, in connection with the nitrates. This well was separated from the gravel stratum by two feet of soil and was only 12 feet from A. There was no more relation between the quantities of nitric acid in these wells, nor in its variations, than between it and wells farther removed.

§ 109. A careful consideration of the results at my disposal do not justify me in making any comparison or assuming any relation as existing between the nitric acid in the waters of these different wells. There is a general similarity in their conduct, but it is greatly modified by, if not wholly dependent upon, the soil conditions in the immediate neighborhood of the well. Well A, on July 8th, before irrigation, showed the presence of 1.79 parts per million and well G only a trace; on the 11th, after irrigation, A showed 15.2 parts and G 19.2 parts of nitric acid per million; by the 25th inst., the nitric acid in A had fallen to 6.59 parts per million, and in G to 2.69 parts. The water plane was nearly the same in the two wells, it being 0.18 of a foot higher in G than in A.

§ 110. The relation between the amount of nitric acid and the total solids is even less intimate than that of the chlorin to the total solids, which is practically equivalent to stating that there is no relation between them.

§ 111. An examination of the 300 determinations of the nitric acid in this ground water does not permit us to draw any conclusions in regard to the effect of either the physical condition of our soil or of the amount and character of our alkalies upon the formation of nitric acid in the soil. The average of the soil samples taken to a depth of two inches indicates the presence of 469 pounds of potassic nitrate or its equivalent in every acre of soil

taken to this depth, *i. e.*, two inches, which is a goodly supply. Our determinations, however, show that this statement cannot be extended to the second two inches, and much less to the first foot of soil, the conventional depth on which to base such computations. Whatever the effects of our conditions may have been, they were certainly not prohibitive of the production of nitric acid.

§ 112. I can find no examinations of ground waters with which to compare my results. The nitric acid in drain waters is another question, and I shall subsequently, in another bulletin, show that drain waters and ground waters from the same territory are not comparable, so that nitric acid determinations in drain waters are not available for my present purpose. I am compelled by the lack of better data to use samples of another ground water taken by myself as the basis of my statements in regard to the effects of our conditions upon this subject.

§ 113. A sample of ground water from a field lying to the west of my plot, several feet higher, and of an entirely different aspect and character, was taken 10 days after irrigation and showed the presence of 0.718 part of nitric acid per million. This land is in good condition, is not alkalized, water logged, or subject to the adverse conditions obtaining in my plot. The field, however, was in alfalfa at the time the sample was taken, July 5th, and the sample represented the ground water in the soil at that time, for the sample was taken immediately after the hole was dug. The nitric acid in this sample is lower than was usually found in ground water from my plot, but is not so low as was sometimes found in it, but as these smaller quantities are exceptional, it is probably safe to conclude that the ground water in my plot is quite as rich, or even richer, in nitric acid than the average ground water of the neighboring soils.

I did not know, nor even suspect at the time these samples were taken, that I could not compare them with drain waters, nor did I fully appreciate the fact that a sample of water taken from the soil represented so little beyond the conditions prevailing within a very few feet of the point where it was taken.

§ 114. Judging from the amount of nitric acid found in the aqueous extract of the soil, especially in that from the first two inches and from the amount usually present in the ground water as represented by the wells, ranging up to 6 or 8 parts per million, but as a rule from 2 or a little less to 5 parts per million, the alkalized condition was not unfavorable to the formation of nitric acid, The abundance of proteids in the beet crops grown on this ground. they being slightly higher than the average in this respect, also support this view.

§ 115. The great difference in the amount of nitric acid in the first and second two inches of soil, suggested the question of a possible reduction of the nitric acid from some cause. I had no reason to suspect the formation of ferrous salts, and the amounts of ammonia and nitrous acid found in the well and drain waters examined for these constituents did not strongly support the idea of a reduction. The maximum amount of free ammonia found in the well waters before irrigation was 0.0850 part per million, and after irrigation 0.5780 part. The maximum quantity of nitrous acid found in the well waters before irrigation was 0.0837 part per million, and after irrigation 0.1000 part. The increase in the free ammonia present after irrigation is not accompanied by a corresponding increase in the nitrous acid, but is greatly exceeded by the increase in albumenoidal ammonia, so that the probabilities are in favor of another source for it rather than that of the reduction of nitric acid. The nitric acid in these samples was, moreover, quite as high as the average, being 2.692 parts per million before irrigation and 7.628 parts per million after irrigation.

§ 116. When we consider the large amount of nitric acid per acre, 293.14 pounds, existing in the uppermost two inches of this soil, and while the second two inches show less than a tenth as much, and further, that the ground waters are comparatively poor in it after as well as before irrigation, we are forced to the conclusion that there is a tendency in our soil to the concentration of this salt in the upper portions. Whether this is due to a very rapid formation of it at this point, or to the action of capillarity under our meteorological conditions, is an open question. Long continued cloudiness, with or without continued or heavy rains, which means impeded evaporation, is followed by a greater increase in the amount of nitric acid in the ground water than we have observed to be due to irrigation. In fact the increase due to irrigation has in no case been comparable to that observed after long rains. I have no explanation to offer for this fact unless we find one in the difference between the rate at which the nitrates tend to move upward, due to capillarity, whose effects are made more marked by our conditions, almost continuously favorable to a rapid evaporation from the surface and that at which they may be washed downward by the amount of water used. It is well known that the nitrates appear in alkaline crusts under favorable conditions, sometimes forming several per cent. of the mass, but I have not found it present in any incrustation collected in Colorado except in traces.

§ 117. I expected to find relatively large quantities of nitrates n the ground water, owing to the fact that the soil is not usually credited with any great power of retaining them when solutions of these salts are passed through them, and I at first assumed that

there was enough downward moving water in the soil, even when the voids between the soil particles were not completely filled with water to carry the nitrates into the ground water. Such does not seem to be the case, for if it were, the ground water immediately after irrigation ought to be richer in nitrates than they were found to be, even after making liberal allowance for the fact that the irrigation might effect a dilution of the ground water. In the case of the total solids we find a very decided increase, more salts having gone into solution than was necessary to maintain the degree of saturation. This is true, too, of the nitrates, at least in a measure. In the case of the irrigation applied August 31st and September 1st, 1899, the results were not uniform in regard to the increase of the nitrates in the ground water, indeed an increase in their quantity was the exception. This result was probably due to the fact that I had a more liberal supply of water than in any previous irrigation and the results were due to dilution of the ground water, owing to the addition of a large quantity of water in a short time.

NITROUS ACID IN THE GROUND WATER.

§ 118. I have given the limits found for the nitrous acid in the ground water, especially before and after irrigation, in a preceding paragraph. Our examination of the water did not as a rule extend to the determination of this constituent except in studying the effects of irrigation upon the composition of the ground water, offflow and drainage, under which topic the results observed will be given more fully. The results of the determinations made indicate that as a rule the nitrous acid present in the ground water of this plot was low, not exceeding 0.0837 part per million, except immediately after irrigation, when it rose to 0.1090 part per million. The least quantity of nitrous acid was found in the ground water from the alfalfa field west of our plot, in which we found only a trace.

§ 119. The few samples of drain water which we examined were richer in nitrous acid than the ground waters. The ground waters were richer in nitric than in nitrous acid; while the reverse was the case with the drain waters. The cause of this might be a reduction of the nitrates in passing through the soil to the depth of the drain, which is about four feet, but the ratio of increase above that of the nitrates caused by irrigation suggests that it is rather due to the deportment of the salts of this acid toward the soil particles. For while irrigation did not always increase the nitrates in the ground waters, it always increased the nitrites, and in those cases in which it caused an increase of the nitrates from $1\frac{1}{2}$ to 3 times their previous amount, the nitrites were increased from 8 to 30 or more times. It should be remembered that we always had very much smaller amounts of nitrites than of nitrates to deal with.

The presence of larger quantities of nitrites in the drain than in the ground water is more probably due to the deportment of the solution of these salts within the soil than to a reduction of the nitrates. This view is suggested by the facts stated above, and also by the fact that the off-flow water is poorer in nitrates than the ground water either before or after irrigation, while the nitrites in the off-flow water amounted to more than 200 times as much as was found in the ground water, but the amount was less than that which was found in the drain waters. I do not maintain that there is no reduction of the nitric to nitrous acid taking place in this soil, but simply that the appearance of the nitrous acid in the drain and off-flow water in excess of the nitrates does not necessarily indicate a reduction of the nitric acid, but is probably to be explained in this case by the different deportment of these salts after they have been formed, without regard to the method of their formation. I stated in a former paragraph that I had no reason to assume the formation of ferrous salts or the presence of other conditions favoring the reduction of the nitrates in any unusual degree, micro organisms not included.

AMMONIA IN THE GROUND WATER.

§ 120. The ammonia and ammonia salts in the soil were shown in Bulletin 65 to probably amount to a little more than 0.00211 per cent. of the soil. The amount of these salts in the ground water is small, ranging from 0.0230 to 0.0850 part per million. Irrigation increased this amount to from 0.0570 to 0.5780 part per million. The drain waters were found to contain from 0.0496 to 0.0944 part per million.

§ 121. The albumenoidal ammonia present ranged from 0.0674 to 0.3029 part per million in the ground water and was greatly increased by irrigation. The maximum found after irrigation was 3.1170 parts per million. This kind of ammonia does not pass into the drain very freely; it amounted to 0.2299 part per million in the drain water from this plot. The comparatively small amount of ammonia found in the drain waters strengthen the statement made relative to the reduction of the nitrates to nitrites. The reader may be tempted to think that we intend to discuss the potability of this water. Such is not the case. It is purely a matter of the soil conditions. It is for this reason that certain properties of the water are not discussed at all.

AMOUNT OF NITRATES, ETC., REMOVED BY THE IRRIGATION WATER.

§ 122. The question as to how much of the nitrates, nitrites, and ammonia of both kinds was taken from the soil by the water naturally suggests itself. This question is difficult to answer in regard to the ground water, for there are a number of considerations

entering into the answer which are not known with sufficient definiteness. The same may be true of the off-flow water, but this water is the same that flowed onto the soil, and, after having been in contact with it for a certain length of time, flowing over it for a distance of 600 feet in this case, was collected for examination. The water as it flowed onto the soil contained only traces of nitrates; the first portions that flowed off contained 1.970 and 1.077 parts per million respectively; the last portions that flowed off contained 0.3590 and a trace respectively.

§ 123. The ground water in two instances showed an increase in the nitrates from 1.970 and 2.513 to 3.231 and 7.628 parts per million respectively. In two other instances a slight decrease was observed.

§ 124. The rapid diminution in the amount of the nitrates removed by the off-flowing water shows that their removal by the water flowing over the soil is very limited, probably confined to the very surface of the soil. In this connection I would recall the fact that comparatively large quantities of nitrates existed in the upper two inches of this soil. It is evident that the water upon coming in contact with the soil wets the uppermost portion before flowing over it; this takes place even when there is a good head of water. This wetting means a downward movement of the water at first, which may carry the nitrates not somewhat firmly held by the soil, down into the soil and beyond the action of the succeeding, overflowing portions of water.

§ 125. It is stated above that two instances of a decrease in the nitric acid were observed after irrigation. This decrease was in wells B and D and amounted to 0.1840 and 1.0870 parts per million respectively. In the case of D, which was near the point at which the water was brought onto the plot and where the soil was a sandy loam, it may be that the irrigation water may have found its way into the well more directly than it was intended it should, or it may be that the amount of water received at this point sufficed to produce leaching, but I am very doubtful of this.

§ 126. The water, especially the ditch water, used for irrigating, contained an unusual amount of nitrous acid. Whence it came I did not attempt to ascertain, and it was probably not true of the water after it had been running for some hours. Some of the water used was what we designate as seepage water, and contained 0.2340 parts nitrous acid per million. The off-flow was from 3 to 8 times as rich in nitrous acid as the ground water after irrigation. The amount of the off-flow was comparatively small. What relation it bore to the amount applied, I did not determine, nor have I any means of estimating how long the water collected was in contact

with the soil. No account has been taken of the amount of water evaporated, which was probably a larger fraction of the water applied than we would think, possibly not less than a sixteenth of it. The rate of evaporation from a standard tank at the time this irrigation was made was 6 inches in 30 days, and as our irrigation extended over 3 days, the evaporation probably amounted to fully .6 of an inch.

It required about 34 hours for the water to flow the length of the plot, 600 feet, and produce an off-flow. The first samples of the off-flowing water were taken soon after the off-flow began, and the second samples were taken 8½ hours later. At this time the off-flow was estimated to be about half of the on-flow.

§ 127. The albumenoidal ammonia in the ground water was materially increased in two of the wells, but in the other two wells its amount was affected in a very much less degree. The off-flowing water was only slightly richer in this kind of ammonia than the on-flowing water.

§ 128. The rate at which the water flowed over the ground and also the rate at which it passed into the soil probably exerted an influence upon the amount and kinds of salts taken into solution. An attempt was made to determine the rate at which the wells filled; they were measured, pumped down, remeasured, and the time noted which was required for them to fill again. The rate varied with the soil and other conditions, but our results indicated an inflow of from 7 to 11 cubic inches per minute, the water outside of the wells standing from 24 to 36 inches above the surface at the beginning of the experiment. This does not indicate so rapid a draining out of the water from a comparatively free surface as I expected. The surface varied in the different wells, but this requires nearly 30 square inches to furnish one cubic inch of water per minute, or a square foot yielded at the rate of 4.8 cubic inches per minute. No attempt was made in this crude experiment to find out how much space about the well was affected by the lowering of the water in the well; it was very small at best. This rate of inflow would have diminished materially after a short time. I have elsewhere stated that the lateral movement of the solutions, which may be quite equivalent to water, is very small, if not zero, in this plot, for the amount and kinds of salts in the water in wells near to one another are different and maintain their individuality throughout a series of changes in the conditions of the ground water, including the effects of irrigation. The rate of the flow into the wells does not seem to be sufficiently high to disturb the relation of the well water to the ground water to such an extent as to demand special consideration. The differences between the ground waters and aqueous extracts of the soil already noted are not sensibly affected by the lat-

eral passage of the solutions through the soil and probably not by their downward movement in the plot under discussion. If the conditions were changed, for example, by judicious and thorough drainage, then the question of alkali salts in the soil would be one of time and the amount of water applied to the surface. Our object from the beginning was not to study the effects of drainage as such, but the effects of cropping and cultivation where irrigation is necessary but drainage difficult or impossible.

SUMMARY.

1. The question of alkalization in Colorado resolves itself into a question of drainage.

2. Alkalization in this state has been made more apparent, and its effects increased, by over irrigation.

3. Crops growing on alkalized soil with the water table quite near the surface were sensitive to drouthy conditions.

4. The water plane is 1.83 feet higher at the west end of the plot than at the east end and the drainage is probably to the eastward.

5. The inclination of the water plane to the eastward is less than that of the surface.

6. The height of the water plane often changes without sensible cause, probably due to atmospheric conditions, pressure, temperature, etc.

7. Light rains during dry periods produce, as a rule, comparatively great increases in the height of the water plane, probably due to modification of the capillary conditions.

8. Light rains during an interval of abundant moisture when the soil is wet do not produce an increase in the height of the water plane.

9. Moderate rains were sometimes accompanied by temporay depression of the water plane. This was accounted for by the rate of rain fall, character of soil and the air contained therein.

10. The effect of an irrigating ditch running past the east end of the plot was to raise the height of the water plane by 0.30 of a foot at a distance of 142 feet from the center of the ditch. This raise was apparently produced by the causing of a backward pressure and not by direct infiltration of water.

11. When the water plane rose due to changes in capillary conditions caused by light rain falls it usually fell to its former level in about three days, but when it rose after an irrigation it required from 10 to 13 days for its fall.

12. The total solids, salts held in solution in the different well waters,

varied both in quantity and in the ratio of the different salts present. Their amount and character depended upon the conditions obtaining in the immediate vicinity of the well.

13. The total solids rose and fell with the water plane, passing into the water as it rose, and remaining in the soil when it fell. This is the same as saying that the total solids in solution depend upon the relative masses of the water and soil and vary with the character of the soil, including the salts retained in it. The preceding is a general statement and does not consider the irregular increase or decrease of the total solids in the same well at different times. These are unquestionably dependent in a large measure upon the unlike conditions of chemical equilibrium obtaining in the solution at different times.

14. The increase in the amount of total solids in a well water is not always the greatest in those wells which show the greatest rise in the water plane, nor in those which usually show the greatest quantities of total solids. The increase in the total solids due to the rise of the water plane seems to be partly dependent upon the rate of diffusion through the soil.

15. The height of the water in the different wells was essentially the height of the water table in the soil.

16. The total solids in the well waters were less than in the water in the soil. This difference was not due to a mixture of water entering the wells from different sources, but was seemingly due to the modification of the laws of diffusion and solubility by the soil itself.

17. The total solids in the ground water were lower in 1899 than in 1897 as indicated by samples of ground water taken 10 days after irrigation.

18. The chlorin, or its corresponding salt, sodic chlorid, was at no time very abundant in the ground water and bore no definite relation to the total solids, as the sodic chlorid ranged from 5 to a little more than 14 per cent. of their total weight. The increase or decrease of sodic chlorid, common salt, was not proportional to the increase or decrease of the total solids and did not serve as an index of either the amount of total solids present or of their variation, except within very wide limits.

19. The chlorin may not always be present in the form of sodic chlorid, which is tacitly assumed in the preceding statement. Analytical results indicate that it may sometimes be present as magnesic chlorid, and the irregular deportment of chlorin in the waters may be due to such causes, *i. e.*, differences in the manner of its combination.

20. The chlorin present in the ground waters and its variations in quantity throw but little or no light upon the movement of the alkali salts within this soil.

21. The term total solids is equivalent to the salts constituting the free solution in the soil. The term represents a different mixture of salts than is found in the incrustations forming on the surface of the soil, or obtained by evaporating an aqueous extract of the soil to dryness.

22. The total solids in the ground water varied greatly in the different wells, and also from time to time, in regard to their quantity, but only to a limited extent in their chemical composition. The difference in the latter respect was almost exclusively confined to the relative quantities of the respective salts.

23. The method of combining the analytical results has been adopted as convenient and probable, but not as infallible.

24. In combining up the analyses there is frequently a slight excess of sodic oxid, this is often within the limits of analytical errors, at others it is rather high. We have observed that this excess is usually higher when the loss on ignition is high and are inclined to attribute it to the presence of organic acids.

25. The alkali incrustations from this plot consist essentially of sodic

and magnesic sulfates in the ratio of two to one; they together constitute 80 per cent. of the mass. Calcic sulfate is subordinate in quantity with sodic chlorid and carbonate still more so.

26. The salts dissolved in the ground water, the total solids, consist much more largely of calcic sulfate than of sodic sulfate, and contain about the same amount of magnesic sulfate as the incrustation from this plot. The ratio of calcic sulfate to the magnesic and sodic sulfates in the total solids is approximately 2:1¼:1.

27. The salts extracted from the first two inches of the soil by continued treatment with water consisted of the same salts, they made up nearly 80 per cent of the total, but the ratio was approximately 4:2:1.

28. The aqueous extract of the second two inches of soil contained very little magnesic sulfate, no sodic sulfate, and almost 51 per cent. of calcic sulfate. This extract showed a large amount of soluble silicic acid, corresponding to 14.5 per cent. of sodic silicate calculated on the dried residue.

29. The upper portions of the ground water are richer in total solids than the successively deeper portions and the salts in solution differ, especially in their relative quantities.

30. There seemed to be an abundant formation of nitric acid in the upper portions of the soil, even in portions of the plot where the alkali salts were abundant.

31. Nitric acid occurred so generally in the ground waters and its variations were so dependent upon other conditions that we cannot judge of the effect of the alkalies present nor of that of the mechanical conditions.

32. There was no relation between the amount of total solids and that of the nitric acid present.

33. There was no relation between the different wells in regard to the quantity of nitric acid present or its variations.

34. Irrigating the ground increased the nitric acid in the well waters, so did even light rainfalls, probably due to increase of capillary exchange of the nitrates between the upper portions of the soil and the ground water.

35. The ground water from this plot is richer in nitrates than that from neighboring land which is in better condition.

36. The nitrites in the ground water are relatively high and are increased by irrigation. This is probably due to the biological conditions of the soil and the deportment of solutions of nitrites toward the soil, especially in regard to the readiness with which they will pass through it.

37. The free ammonia and ammonia salts were not especially abundant in the ground water, either before or after irrigation, though more abundant after than before.

38. The ground water was slightly richer in free ammonia than the drain water from this plot.

39. The albumenoidal ammonia in the ground water was not excessively high, but it was materially increased by irrigation. The albumenoidal ammonia did not appear to pass freely into the drain water.

40. The amount of nitrates removed by off-flow water is probably quite limited as their quantity in the off-flow diminished rapidly.

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Bulletin 73. August, 1902.

The Agricultural Experiment Station

OF THE

Colorado Agricultural College.

PART I.

THE FEEDING VALUE OF BEET PULP.

PART II.

FEEDING BEET PULP AND SUGAR BEETS TO COWS.

BY

B. C. BUFFUM and C. J. GRIFFITH.

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THE FEEDING VALUE OF BEET PULP AND FEEDING BEET PULP AND SUGAR BEETS TO COWS.

BY B. C. BUFFUM AND C. J. GRIFFITH.

PART I. INTRODUCTION.

The natural conditions in arid America where a comparatively small part of the land is reclaimed by irrigation and the rest will always be used as range for live stock, make the stock industry one of the most important features of our Agriculture. With the development of our irrigated farms has come smaller holdings of better classes of stock than those originally pastured on the ranges, and the farmer has become desirous of finishing his stock for market at home instead of selling feeders to be fattened in the corn growing states east of us.

The growing of alfalfa on our farms to supply a rotation which will keep up the fertility of the soil has become an indispensible practice and this surplus hay is an important item of profit if it can be fed at home.

Establishing the beet sugar industry has brought to our farmers another source of stock foods in the by products of the sugar factories, the most important of which is the beet pulp which is left after the sugar has been extracted. The coming winter we estimate that the factories now established in the state will produce over 150,000 tons of this pulp which will be available for feeding stock. Our farmers are customers for large quantities of corn shipped in from Kansas, Nebraska and Iowa, for which they pay large prices in order to enable them to profitably use their alfalfa in fitting stock, more especially lambs, for market. Anything which will make our own people more independent by producing their own feeds instead of purchasing from abroad is of inestimable value to the state. The Experiment Station is continually trying to solve this problem and furnish the information it may gain to those who can make use of it. The feeding value of sugar beets and of beet pulp, the comparative value of our home grown grains, and corn and of such new grains or new stock foods of whatever nature, and the combinations of these foods which will give the largest returns, are important questions which have been receiving marked at-

tention recently. We are now ready to publish bulletins giving the results of a series of experiments which have been carried out to throw light on these questions. An experiment has been carried out on the sub-station at Rockyford by Mr. Griffin, to show the value of beet pulp combined with alfalfa for lamb feeding. In the present bulletin we give a brief resume of the value of beet pulp as determined in other places and report some trials in which beets and pulp were fed to cows on the College farm at Fort Collins. The information of the value of pulp as determined in other places has been gleaned from every available source which we have reason to believe is reliable and in connection with our own investigations will give our farmers and stockmen some basis upon which to decide whether or not it will pay them to feed pulp to their stock. In addition to this bulletin, we have ready for publication a bulletin on "Swine Feeding in Colorado" which reports trials with beets and pulp and which gives the only information we know of about the value of beet pulp for hog feeding, and also a bulletin entitled "Lamb Feeding Experiments in 1901-1902," in which will be reported the results of our trials of pulp and beets in rations for fattening lambs. We speak only of the diffusion pulp such as comes from our factories.

COMPOSITION OF BEET PULP.

Professor Henry in his book "Feeds and Feeding" gives the result of sixteen analyses and seven trials of digestibility of beet pulp, which shows the following composition. The digestible nutrients are given:

BEET PULP. AVERAGE OF 16 ANALYSES.

Dry Matter.	Protein.	Carbohydrates.	Ether Extract.	Nutritive Ratio.
10.2	0.6	7.3	—	1:12.2

Analyses made by the California Station, published in their bulletins, show a nutritive value considerably higher than the above. These analyses also show the comparative value of beet pulp, pulp silage and sugar beet silage.

The digestible nutrients only were calculated.

CALIFORNIA BEET PULP.

	Water.	Protein.	Carbohydrates.	Fat.	Feed Value Calories.	Nutritive Ratio
Beet Pulp	90	1.25	8.19	0.14	164	1:6.7
Beet Pulp Silage	90	1.46	7.84	0.39	165	1:5.7
Sugar Beet Silage	70	4.38	23.52	1.17	351	1:7.7

Analyses made by Dr. Headden, Professor of Chemistry

at the College, shows our Colorado pulp to have the following composition:

COLORADO BEET PULP.

Dry Matter.	Protein.	Carbohydrates.	Fat.	Nutritive Ratio
10.0	0.38	7.36	0.2	1:20.5

The crude fibre and nitrogen free extract were reported separately but we combine them under carbohydrates. According to the Calfornia analyses, the beet pulp silage has a narrower ratio and a little higher food value than the fresh pulp, which seems to be the general experience in practice. It will be noted that the fresh pulp is apparently worth between one-third and one-half as much as the sugar beet when made into silage.

The places are not given where the analyses reported by Henry were made; possibly they were all from Europe, and if so, it is possible that the diffreence between the beet pulp there and in this country would be as great as that shown. The analysis given in the Report of the United States Department of Agriculture as an average analysis, is about midway between the ones given above.

The nutritive ratio from the analysis is given as 1:7.2, which it is pointed out, is near the standard ratio for a fattening steer, according to the given standard.

The analysis of the Colorado pulp gives a lower amount of protein and a little more carbohydrates and fat than the composition as given by Professor Henry. This makes the nutritive ratio correspondingly wide.

RESULTS OF FEEDING TRIALS.

EUROPE.

Some experiments in feeding pulp in Europe as given in the year book of the U. S. Department of Agriculture for 1898 are of especial interest to us, as the roughage used was alfalfa hay, the ration being enriched by using linseed oilcake. The following table presents these results. The value per ton of pulp is computed from increase in weight and value of other foods given.

ANIMALS.	FEED.				
	Pulp. lbs.	Alfalfa. lbs.	Linseed Cake. lbs.	Grain per Day. lbs.	Value of Pulp per Ton.
Beef Cattle	115.0	6.6	6.6	2.214	$1.18
Oxen	126.8	12.0	2.2	——	0.87
Sheep	11.8	1.1	0.44	0.3	1.58
Ewes	——	——	——	——	1.10
Average					$1.18

It was stated that the oxen fell off in flesh the first fifteen days on pulp, but after that they gained and did more work on the pulp ration. The ewes were given a little larger ration than the sheep. An experiment in feeding milk cows was said to be even more satisfactory but the comparative value of the pulp was not indicated.

CALIFORNIA.

The California Experiment Station has published some general statements regarding the value of pulp. Different stockmen replied that they could afford to pay from 25 cents to $1.00 per ton for beet pulp. One man placed the value of fermented pulp at 25 cents per ton more than fresh pulp. The pulp there is fed with oat and barley hay and straw, along with chopped grain and cottonseed meal. It is claimed that the meat dresses whiter and with less sinews when fed pulp. An experiment is reported in which pulp was fed to cows and its effect on feed consumed, milk flow and butter fat noted. An accurate account of the hay was not kept, but approximately when no pulp was fed, the cows consumed twenty pounds of hay per day, in addition to eight pounds of grain. When given pulp, the consumption of hay varied from 6 to 16 pounds, depending upon the amount of pulp, which varied from 20 to 80 pounds per day. The effect on the milk flow was beneficial, but there was no appreciable effect in raising or lowering the proportion of fat in the milk.

MICHIGAN.

The Michigan Experiment Station has carried out some interesting experiments in feeding beet pulp. In one experiment pulp was fed to steers at the rate of 55 pounds per day along with mixed hay, shredded corn stover and ground grain. The amounts of foods given and eaten were compared with a check lot not given pulp. It was found that one ton of pulp took the place of 421.5 pounds of corn stover, 274 pounds of mixed hay and 68.8 pounds of grain. At Colorado prices of $4.00 per ton for the roughage and 1¼ cents per pound for the grain, this would give the pulp a value of $2.25 per ton.

In another experiment 13,775 pounds of pulp gave an increased gain of 280 pounds of beef. Giving the increased gain a value of 7½ cents per pound would indicate that the feeding value of the pulp was a little more than $3.00 per ton.

Experiments with milk cows showed that the pulp, when given with hay and grain, increased the flow of milk some-

what but did not add to the yield of butter fat. This report states that owners of growing and fattening cattle declare that pulp saves one-third of the coarse fodder.

NEW YORK.

The Cornell Station reports experiments in feeding beet pulp to cows. Their conclusions are as follows:

"The cows, as a rule, ate beet pulp readily and consumed from 50 to 100 pounds per day, according to size, in addition to the usual feed of 8 pounds of grain and 6 to 12 pounds of hay."

"The dry matter in beet pulp proved to be of equal value, pound for pound, with the dry matter in corn silage."

"The milk producing value of beet pulp as it comes from the beet sugar factory is about one-half that of corn silage."

"Beet pulp is especially valuable as a succulent food, and when no other such food is obtainable it may prove of greater comparative value than is given above."

In the dairy districts of New York and other states where factories have been established, beet pulp is coming into great demand for cows.

NEBRASKA AND OTHER PLACES.

In New Mexico, sheep, and in Utah, cattle, have been successfully fattened and put on the market with no other food than pulp and alfalfa hay.

In Nebraska some valuable data has been obtained with both sheep and cattle. Experience there indicates that a maximum amount of 40 or 50 pounds pulp per day for each steer gives better results than larger amounts. Mr. John Reimers, whose report on pulp feeding has been often quoted, states that cattle eat the same amount of hay and grain when given only moderate amounts of the pulp, but that they lay on flesh more rapidly, shortening the feeding season, and that the pulp gives extra gains of from 50 to 75 pounds in three-fourths of the usual time, which results in a great saving of grain and roughness. His pulp-fed cattle dressed and shipped as well as any other, even for export. Many general reports have been made by those who have fed this important by-product of the sugar factories and all testify to its value both for fattening and the production of milk.

In Colorado some extensive feeding has been done with with pulp. Several feeders in the Arkansas Valley have fed large quantities to both sheep and cattle during the past two years. Col. J. A. Lockhart at Rockyford fed 3,700 head of

cattle during the past winter using beet pulp, alfalfa hay, sorghum, cotton seed meal, corn and bran. He has kindly offered to furnish the Station with his results, and as the feeding was done on so large a scale the data obtained will be very valuable. Mr. Rhodes, of Las Animas, fed 2,200 lambs on pulp, and speaks very highly of the pulp. There was practically no loss of lambs, they made large gains, and he states that the saving of hay while they were receiving the pulp was very marked. Several feeders at Loveland, Colorado, who fed pulp last season will feed on a larger scale the coming winter. Mark Austin, the Agricultural Superintendent for the Loveland Sugar Factory, profitably fed lambs and cattle, and Wm. Davis, a farmer north of Loveland, tells us that his cattle did exceeding well on the pulp ration.

USE OF PULP.

It should be stated that the attempts to compute the cash value of pulp compared with other foods do not indicate its total value. It supplies a succulent food at a time when such food is either not available or is scarce, and its effect on stock seems to be much more favorable than either its chemical analysis or the return in increased meat or milk would indicate. To its actual nutritive effect as a food should be added its general effect on the quality of meat and milk and on the animal system. Pulp undoubtedly overcomes much injurious effects of dry and concentrated foods, puts the system in good sanitary condition, keeps off disease, and so aids the appetite and digestion and assimilation of food that there is less waste, both of food which is generally discarded in eating, and that which usually passes through the animal undigested.

There seems to be no difficulty in regard to keeping beet pulp. While there is some loss of material when placed in open piles, the fermentation which takes place seems to be beneficial rather than otherwise. Animals eat the sour pulp as well, and after a little time even better than they do the pulp fresh from the factory, and the dry beet chips on the surface of the piles are very palatable to sheep and cattle. Nebraska feeders claim that pulp which has been left in open piles for two or three years is as good as ever.

No injurious effects have been observed from feeding pulp, unless too large amounts are given before the animals become accustomed to it. The Michigan Station warns feeders against too liberal use of pulp from frozen beets. Freezing does not seem to injure the pulp itself, except that it

probably does not pay to feed large amounts of frozen pulp in cold weather, as the animal must expend much food energy to raise the temperature of the pulp to the heat of the body. Utah reports a case of the pulp becoming poisoned in shipping. The pulp was shipped in freight cars which had been used in shipping lead ores from the mines, and the pulp absorbed enough of the lead to make it dangerous to stock.

During the past spring the Denver papers gave an account of cattles mouths becoming sore from eating pulp, claiming that the injury was produced by acids added to the pulp in the process of manufacture. This is hardly possible, as the pulp is subjected to nothing but hot water at the factory. Through the process of fermentation from long keeping butyric and acetic acids develop in pulp, but we have no accounts of any injurious effects from feeding fermented pulp.

The greatest difficulty with pulp feeding is that the large amount of water it contains makes it heavy and rather expensive to handle, and it is sometimes difficult to keep the animals dry and comfortable while feeding large amounts of it. The feeder who is near the factory and has the appliances so arranged that he can handle the pulp with the least expense, should make the greatest use of pulp and will gain the greatest profit from its use. If it can be placed before stock at a cost of not more than one dollar per ton, we believe it will bring good returns for the investment, and in many instances it may be worth two or three times this amount. Whether fresh, fermented, or dry, beet pulp is a valuable stock food, and one of which our farmers should make the largest possible use.

As an example of how pulp may be combined with other foods in forming a ration, we give the following illustration:

RATIONS WITH BEET PULP.

FATTENING CATTLE WEIGHING 1,CCO POUNDS.

FIRST PERIOD.

		Dry Matter.	Protein.	Carbo-hydrates.	Fat.	Nutritive Ratio.
Standard Ration		30	2.5	15.0	0.5	1:6.5
Alfalfa	15 lbs.	13.7	1.65	5.94	0.18	
Beet Pulp	75 "	7.6	0.45	5.47		
Cotton Seed Meal	2 "	1.8	0.75	0.3	0.24	
		23.1	2.85	11.71	0.42	1:4.4

SECOND PERIOD.

		Dry Matter.	Protein.	Carbo-hydrates.	Fat.	Nutritive Ratio.
Standard		30	3.0	14.5	0.7	1:5.4
Alfalfa	15 lbs.	13.7	1.65	5.94	0.18	
Beet Pulp	25 "	2.5	0.15	1.8		
Cotton Seed Meal	2 "	1.8	0.75	0.3	0.24	
Corn Meal	6 "	5.36	0.46	4.0	0.26	
		23.36	3.01	12.04	0.68	1:4.5

The larger part of the above information has been gleaned from the following authorities:

Colorado Experiment Station Bulletin No. 46.
Cornell Experiment Station Bulletin No. 183.
California Experiment Station Bulletin No. 132.
Michigan Experiment Station Bulletin No. 193.
Yearbook U. S. Department of Agriculture 1898.
Special Reports, Division of Chemistry, U. S. Department of Agriculture, 1897, 1898, 1899.
Utah Experiment Station Bulletin No. 74.

FEEDING BEET PULP AND SUGAR BEETS TO COWS.

PART II. INTRODUCTION.

The experiments here reported were among the first planned to compare the feeding value of sugar beets and pulp from beet sugar factories. The value of roots to furnish succulent food during the winter when green pasture is not available, has long been well understood, and such succulent foods are considered especially desirable for cows producing milk. The pulp has a smaller nutritive value than beets because the sugar and salts which have been extracted at the factory are important food products, but there is no question about its succulence. Fresh pulp contains about ten per cent more water than beets. If the office of roots in a ration is to supply juicy foods which will aid in the digestion and assimilation of the roughage and grain fed with it, rather than for the nutritive effect, we would expect pulp to possess the necessary qualifications. The manufacture of silage from corn and other roughage is done to extend the summer conditions of green food through the rest of the year when the animal's system is apt to become clogged with dry grain and dry hay to such an extent that the digestive tract does not perform its normal function.

That the main use of roots or beet pulp is to prevent mal-nutrition and insure general health, rather than to supply food, can hardly be questioned. Food nutrients can be supplied in concentrated form, but in order for the animal to make use of them he must be given bulk to fill up and distend the digestive organs, and the food must be porous and permeable by the digestive fluids. Laplanders eat infusorial earth, which is simply a chalky soil, to help fill up the stomach and dilute the whale blubber which is almost pure fat and forms the chief part of their diet.

Beets or beet pulp given our farm animals supply quantities of tender living plant cells which are filled with juices and which dilute, soften and separate the particles of dry hay and grain so the nutritive qualities of the whole may be more efficiently digested and absorbed out of the mass. This is aptly illustrated by a statement made to one of us by a feeder of long experience. He stated that one winter he followed the usual practice of running hogs with his steers to

consume the undigested corn. The hogs did usually well until he added the beet pulp to the corn ration for the steers, when they so thoroughly digested the corn that the hogs starved and he was forced to give them other food.

Both beets and pulp have nutritive values, that of the beets being greater than that of the pulp. They contain so much water which is merely bulk, that a cow would hardly be able to eat enough of the pulp, at least if given no other food, to supply her maintenance, and there is a limit to the amount of such foods which can be profitably used. Some experiments report cows eating as much as 120 pounds of pulp daily, or forty to sixty pounds of beets. However, excessively large amounts of beets are dangerous, as they contain small amounts of a poison principle which may cause the death of the animal by paralysis, if indeed the mere amount of food does not produce other serious troubles. In all of our experiments up to this time we have confined the amount of beets or pulp fed to a minimum, giving only such quantities as experience in other places has indicated could be fed with profit. We think fifty pounds of beet pulp, or one-half that amount of beets, would be a maximum to add to a ration fed to cows, and in our experiments to show comparative values we have fed approximately one-half as much.

If the main use of beets or pulp is to furnish a tonic or to produce a salubrious mechanical effect, rather than to supply nutriment, then we would not expect to find a great amount of difference in their feeding value when added to grain and hay rations in small amounts. These points should be borne in mind when comparing the results obtained in the following reports of our feeding trials.

The beets fed were grown on the College farm and contained from twelve to seventeen per cent of sugar. The pulp was kindly furnished for the purpose of making the tests by Mr. A. V. Officer, manager of the Loveland Sugar Factory. The pulp was placed in piles on the ground outdoors and fed as wanted.

PLAN OF THE EXPERIMENT.

At first four cows were put on alternate beet and pulp rations, records of which were kept for eleven weeks. Later a fifth cow, Bessie Geneva 2d, was added and fed from the eighth to eleventh weeks. Having obtained five common stock cows before the supply of pulp was exhausted, they were fed in the same manner the last three weeks.

The first week all the cows were given sugar beets; the next two weeks the beets were discontinued and pulp fed;

the fourth and fifth weeks beets were given instead of pulp; the sixth and seventh weeks pulp was fed; the eighth and ninth weeks, beets, and the tenth and eleventh weeks, pulp. The cows were all fed the same amount of hay and grain daily throughout the experiment. The grain was equal parts of corn chop and wheat chop.

There was a slight variation the first week in the amount of grain fed, as the cows were given four pounds of grain per day the first two days, at the end of which time it was increased to eight pounds per day. The first week each cow ate 14.3 pounds of alfalfa per day, and for the remaining time they ate 20 pounds per day. The sugar beets eaten amounted to eight pounds per day during the first week, and twelve pounds per day during the subsequent alternate periods of two weeks each. They ate 24 pounds of pulp daily when given the pulp ration. The rations were as follows:

BEET RATION.

Corn chop, 4 pounds.
Wheat chop, 4 pounds.
Alfalfa hay, 20 pounds.
Sugar beets, 12 pounds.

PULP RATION.

Corn chop, 4 pounds.
Wheat chop, 4 pounds.
Alfalfa hay, 20 pounds.
Beet pulp, 24 pounds.

It is interesting to note how nearly the above rations correspond in digestible nutrients with the theoretical standard for a thousand pound dairy cow giving 22 pounds of milk daily.

	Dry Matter.	Protein.	Carbo-hydrates.	Ether Extract	Ratio.
Standard	29	2.50	13.0	0.5	1:5.7
Our Beet Ration	27.1	3.05	14.6	0.5	1:5.1
Our Pulp Ration	27.8	2.99	14.2	0.48	1:5.1

RESULTS OF THE FEEDING TRIALS.

Tables I to X give the individual records of each of the cows which were fed either beets or pulp for two or more weeks, and Tables XI and XII give in condensed form the records of the five cows which were fed beets one week and pulp two weeks. The minus sign before numbers in columns headed "gain" means a loss of weight for the time indicated.

TABLE I.

DAINTY NOBLE—FED SUGAR BEETS.

Week.	Weight of Cow.			Beets Eaten	Milk	Butter	Percent Fat
	Beginning	End	Gain				
1st.	lbs. 800	lbs. 820	lbs, 20	lbs. 56	lbs. 118.0	lbs. 6.46	4.65
4th and 5th.	820	870	50	168	244.2	13.91	4.87
8th and 9th.	890	830	—60	168	244.5	14.59	5.12
Total.			10	392	606.7	34.96	
Average Weekly.			2	78.5	121.3	6.99	4.88

TABLE II.

DAINTY NOBLE—FED BEET PULP.

Week.	Weight of Cow.			Pulp Eaten	Milk	Butter	Percent Fat
	Beginning	End	Gain				
2d and 3d.	lbs. 820	lbs. 820	lbs. 0	lbs. 224	lbs. 246	lbs. 13.89	4.85
6th and 7th.	870	890	20	336	242.2	13.34	4.72
10th and 11th.	830	880	50	336	252.5	15.17	5.16
Total.			70	896	740.7	42.40	
Average Weekly.			11.7	149.3	123.5	7.06	4.89

TABLE III.

GILDANA—FED SUGAR BEETS.

Week.	Weight of Cow. Beginning	End	Gain	Beets Eaten	Milk	Butter	Percent Fat
1st.	lbs. 930	lbs. 931	lbs. 1	lbs. 56	lbs, 59.0	lbs. 3.19	4.60
4th and 5th.	960	970	10	168	144.2	8.15	4.84
8th and 9th.	960	970	10	168	133.0	7.80	4.93
Total.			21	392	336.2	19.14	
Average Weekly.			4.2	78.5	67.2	3.83	4.79

TABLE IV.

GILDANA -FED BEET PULP.

Week.	Weight of Cow. Beginning	End	Gain	Pulp Eaten	Milk	Butter	Percent Fat
2d and 3d.	lbs. 931	lbs. 960	lbs. 29	lbs. 224	lbs. 136.5	lbs. 7.6	4.79
6th and 7th.	970	960	—10	336	121.7	7.03	4.95
10th and 11th.							
Total.			19	560	258 2	14.63	
Average Weekly.			4.7	140	64.5	3.66	4.87

TABLE V.

YOUNG GRANNIE—FED SUGAR BEETS.

Week.	Weight of Cow. Beginning	End	Gain	Beets Eaten	Milk	Butter	Percent Fat
1st.	lbs. 1070	lbs. 1060	lbs. —10	lbs. 56	lbs. 91.5	lbs. 5.28	4.95
4th and 5th.	1090	1080	—10	168	210.5	12.52	5.10
8th and 9th.							
Total.			—20	224	302.0	17.80	
Average Weekly.			—6.6	74.7	100.7	5.93	5.02

TABLE VI.

YOUNG GRANNIE—FED BEET PULP.

Week.	Weight of Cow. Beginning	End	Gain	Pulp Eaten	Milk	Butter	Percent Fat
2d and 3d.	lbs. 1060	lbs. 1090	lbs. 30	lbs. 224	lbs. 203.2	lbs. 11.68	4.94
6th.	1080	1108	28	168	104.5	5.98	4.89
Total.			58	392	307.7	17.66	
Average Weekly.			19.3	131	102.6	5.88	4.91

TABLE VII.

MOUNTAIN BEAUTY—FED SUGAR BEETS.

Week.	Weight of Cow.			Beets Eaten	Milk	Butter	Percent Fat
	Beginning	End	Gain				
1st.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	
4th and 5th.	970	970	0	168	163.0	7.07	3.51
8th and 9th.	1000	1030	30	168	190.2	7.71	3.47
Total.			30	336	353 2	14.78	
Average Weekly.			7.5	84	88.3	3.69	3.49

TABLE VIII.

MOUNTAIN BEAUTY—FED BEET PULP.

Week.	Weight of Cow.			Pulp Eaten	Milk	Butter	Percent Fat
	Beginning	End	Gain				
2d and 3d.	lbs. 960	lbs. 970	lbs. 10	lbs. 224	lbs. 146.7	lbs. 6.43	3.72
6th and 7th.	970	1000	30	336	178.2	7.43	3.57
10th and 11th.	1030	990	—40	336	192.0	7.65	3.43
Total.			00	896	516.9	21.51	
Average Weekly.			00	149.3	86.1	3.58	3.57

TABLE IX.

BESSIE GENEVA 2d—FED SUGAR BEETS.

Week.	Weight of Cow.			Beets Eaten.	Milk.	Butter.	Percent Fat.
	Beginning	End.	Gain.				
8th and 9th	lbs. 1290	lbs. 1260	lbs. —30	lbs. 168	lbs. 519.7	lbs. 28.16	4.59
Total.							
Average Weekly.			—15	84	259.8	14.08	4.59

TABLE X.

BESSIE GENEVA 2d—FED BEET PULP.

Week.	Weight of Cow.			Pulp Eaten.	Milk.	Butter.	Percent Fat.
	Beginning	End.	Gain.				
10th and 11th	1260	1220	—40	336	557.2	27.23	3.91
Total.							
Average Weekly.			—20	168	278.6	13.61	3.91

TABLE XI.

FIVE COWS ON BEETS.—NINTH WEEK.

Cow.	Weight.			Beets Eaten.	Milk.	Butter.	Percent Fat.
	Beginning	End.	Gain.				
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	
Brindle No. 3.	850	860	10	84	210.7	9.78	3.96
Black Cow.	990	1030	40	84	255.5	12.86	4.38
Red Cow.	880	890	10	84	180.5	8.78	4.11
Brindle.	1030	1040	10	84	234.2	12.68	4.12
Old Spot.	860	870	10	84	170.7	8.10	4.01
Total.			80	420	1051.6	52.20	
Average Weekly Per Cow.			16	84	210.3	10.44	4.12

TABLE XII.

FIVE COWS ON PULP.—TENTH AND ELEVENTH WEEKS.

Cow.	Weight.			Pulp Eaten.	Milk.	Butter.	Percent Fat.
	Beginning	End.	Gain.				
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	
Brindle No. 3.	860	800	—60	336	465.5	20.00	3.70
Black Cow.	1030	990	—40	336	529.0	23.33	3.75
Red Cow.	890			336	376.5	19.13	4.18
Brindle.	1040	935	—105	336	470.7	24.04	4.24
Old Spot.	870	820	—50	336	396.0	18.33	3.95
Total.			—255	1680	2237.7	104.83	
Average Weekly Per Cow.			—32	168	223.8	10.48	3.96

DAINTY NOBLE.—TABLES I AND II.

Dainty Noble is a registered Jersey heifer. At the time of this experiment she was in her first period of lactation, her calf having been dropped January 1, 1902, at which time Dainty Noble was twenty-one months old. Her calf was taken away immediately after birth. Dainty Noble was fed liberally with a ration of wheat and corn chop and alfalfa hay. Sugar beets also formed a part of the ration most of the time until the experiment began, so the beets were not altogether a new food for her, and there would be no undesirable results from change of food ration.

GILDANA.—TABLES III AND IV.

Gildana is an old decrepit Jersey having passed the useful years of her life and is being kept as a nurse cow for unfortunate calves from our beef herds. Gildana's last calf was dropped in August, 1901, from which time she had been milked as her motherly services had not been required elsewhere. She too had been fed sugar beets along with a grain and alfalfa ration. The largest milk record which Gildana leaves is from January 1, 1897, to January 1, 1898, during which time she produced 7,809 pounds of milk. The per cent of butter fat is not recorded.

YOUNG GRANNIE.—TABLES V AND VI.

Young Grannie had dropped her sixth calf in August, 1901, being herself eleven years old the previous May. In her prime she had been a good milker and a large profit cow. Young Grannie is also a registered Jersey. The ration of sugar beets, wheat and corn chop and alfalfa hay had also been fed to Young Grannie.

MOUNTAIN BEAUTY.—TABLES VII AND VIII.

Mountain Beauty is a pure-bred Shorthorn heifer out of Bessie Geneva 2d. As a calf Mountain Beauty was of remarkable proportions. "She is as handsome a calf as I ever saw" were the words of the President of the National Live Stock Association. Mountain Beauty dropped her first calf when she was still very young. It was thought advisable to take the calf away from her, and in despite of the high condition in which she had been kept for the fairs, to see if she would still show the tendency of her dam in the dairy line.

Mountain Beauty had not been accustomed to sugar beets before the experiment as had the preceeding cows.

BESSIE GENEVA 2d.—TABLES IX AND X.

Bessie Geneva 2d dropped her fourth calf April 9, 1902, when she was five years and eight months of age. As soon as her milk was good to use she was put on the experiment, which was in time to give her two weeks each on beets and pulp. This was the second year that she had been milked. Previous to that time her calves had been allowed to take the milk.

Sugar beets had been a part of the ration fed to Bessie Geneva 2d during the winter months of 1901–02.

FIVE COWS IN TABLES XI AND XII.

The five cows reported in these tables were scrub cows purchased to furnish milk to the College dairy. They had calved from two weeks to two months previous to the time they were brought to the College farm. None of them had been given grain or had received anything but pasture grass. When we obtained possession of them they were weighed up and put upon the experiment at once and given the same ration of grain, alfalfa, sugar beets and pulp as were the other cows. These cows are not considered in the results because they were not on the experiment long enough to give an intelligent idea of the effect of the beets and pulp.

It will be noticed in Table XII that four cows made a total loss, during the two weeks that they were fed pulp, of 255 pounds. This is probably explained by the fact that a little more than one week before this time, these cows came directly off of pasture and were put on a grain ration. It would be natural then for them to fill up for some time and apparently gain flesh during the first week on sugar beets, and then apparently lose weight rapidly during the two following weeks. For this reason the results of these cows are not used in computing the comparative cost and profits.

The results for the first five cows which were on feed long enough to make the comparison of sugar beets and pulp of some value, show that the two foods gave almost identical returns. The pulp ration gave slightly better returns when fed to Dainty Noble and Young Grannie. Bessie Geneva 2d gave more milk but not quite so much butter per week when on pulp, and also lost most flesh. The beets apparently gave better returns with Gildana and Mountain Beauty. The per cent fat in the milk varies so much that it is difficult to draw definite conclusions in regard to which ration produced the richest milk. Our averages show a little more milk from the pulp ration and a little higher fat content in milk from the beet ration.

TABLE XIII.

COST AND PROFIT—FROM FEEDING BEETS AND PULP.

AVERAGE WEEKLY.

Cow.	Food.	Cost of Food per Week.			Value Butter @ 20 cts per lb.	Value Gain @ 5 cts. per lb.	Profit from Butter.	Value Milk @ 1 ct per lb.	Profit from Milk.
		Beets.	Pulp.	Total.					
		cts.	cts.	$	$	$	$	$	$
Dainty Noble	Beets	15.7		1.07	1.40	0.10	0.43	1.21	0.24
	Pulp.		7.47	1.00	1.41	0.58	0.99	1.23	0.81
Gildana	Beets.	15.7		1.07	0.77	0.21	– 0.09	0.67	–0.49
	Pulp.		7.0	0.99	0.73	0.23	–0.03	0.64	–0.12
Young Grannie	Beets.	14.9		1.05	1.19	–0.33	–0.19	1.00	–0.38
	Pulp.		6.55	0.99	1.18	0.96	1.15	1.02	0.99
Mountain Beauty	Beets.	16.8		1.09	0.74	0.37	0.02	0.88	0.16
	Pulp.		7.46	1.00	0.72	0.00	–0.28	0.86	–0.14
Bessie Geneva 2d	Beets.	16.8		1.09	2.82	–0.75	0.98	2.60	0.76
	Pulp.		8.40	1.01	2.72	1.00	0.71	2.79	0.78

Table XIII gives the cost of beets eaten, pulp eaten and total cost of all the food for each week, and the values of gain and products with the corresponding profit weekly for each of the five cows which were fed the longest. The cost of the beets eaten is computed from a value of $4.00 per ton on the farm, beet pulp $1.00 per ton, alfalfa $4.00 per ton, wheat chop $1.00 per hundred pounds, and corn chop $1.30 per hundred. The gain or loss in weight of the cows is valued at five cents per pound, and the butter made at 20 cents per pound to give the profit from butter. The amount of butter yield is computed from the amount of fat by increasing the total fat by 16.6 per cent. The profit from the milk production is also given and was computed in the same way, valuing the milk at one cent per pound.

Dainty Noble, on beets, gave a profit of 43 cents per week from the butter, or 24 cents per week from the milk yield. On pulp she gave a profit of 99 cents per week on butter, or 81 cents on milk.

Gildana, when fed beets, gave a loss of 9 cents from butter yield, or of 49 cents from milk yield. On pulp she gave a loss of 3 cents per week from the butter yield, or 12 cents per week from the milk yield.

Young Grannie, when fed beets, gave a loss of 19 cents per week from butter yield, or 38 cents per week from milk yield. On pulp she gave a profit of $1.15 per week from butter yield, which is the highest profit from any of the cows. Her profit is 99 cents per week from milk yield.

Mountain Beauty, when fed beets, gave a profit of 2 cents per week from butter yield, or 16 cents per week from yield of milk. When fed on pulp she gave a loss of 28 cents per week on butter yield, and 14 cents per week from yield of milk.

Bessie Geneva 2d, when fed on beets, gave a profit of 98 cents per week from butter yield, or 76 cents from her milk yield. On pulp she gave a profit of 71 cents in butter or 78 cents in milk.

The difference between the profit and losses made by all the cows while fed beets shows a total profit of 81 cents, against a total profit on pulp of $2.54. Accrediting all of the profit to the total pulp fed gives the pulp a value of $2.61 per ton, and in like manner attributing the profit made by cows on beet ration to the amount of beets which they consumed gives the beets a feeding value of $5.06 per ton.

SUMMARY.

Five cows fed 24 pounds of beet pulp for six weeks, in addition to grain and hay, made an average gain per week of 6.2 pounds. The same cows fed 12 pounds of beets per day for five weeks made an average gain per week of one-fifth pound.

Five cows on the pulp ration gave an average weekly milk yield of 131.1 pounds, and on the beet ration they gave an average weekly milk yield of 127.4 pounds.

Five cows on the pulp ration gave an average weekly butter yield of 6.76 pounds, and on the beet ration an average weekly butter yield of 6.90 pounds. The milk contained a little more butter fat when the cows were fed sugar beets.

A little more than three times as much profit resulted from feeding 24 pounds of pulp per day than was realized from 12 pounds of beets per day, at one dollar and four dollars per ton respectively.

The total profits indicated a feeding value of the pulp for butter production of $2.61 per ton, and of the beets of $5.06 per ton when fed in small amounts, and when butter is worth 20 cents per pound.

Bulletin 74. September, 1902.

The Agricultural Experiment Station

OF THE

Colorado Agricultural College.

SWINE FEEDING IN COLORADO.

BEET PULP AND SUGAR BEETS FOR FATTENING HOGS.

HOME GROWN GRAINS VS. CORN FOR FATTENING HOGS.

OTHER TRIALS WITH CORN, BARLEY, ALFALFA AND BEETS.

—BY—

B. C. BUFFUM and C. J. GRIFFITH.

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SWINE FEEDING IN COLORADO.

(*a*) Beet Pulp and Sugar Beets for Fattening Hogs.
(*b*) Home-Grown Grains *vs.* Corn for Fattening Hogs.
(*c*) Other Trials with Corn, Barley, Alfalfa and Beets.

BY B. C. BUFFUM AND C. J. GRIFFITH.*

The general conclusions which may be drawn from the experimental investigations reported in this bulletin will be found in condensed form on the last pages, and we suggest that the busy man who is willing to accept our testimony may profitably omit the reading of all intermediate material, except the pictures.

The last enumeration of hogs in Colorado (1901) credited the state with 101,198 head. There are, according to the census, 2,273,968 acres of land irrigated, and the farms and ranches number 24,700.

The scarcity of swine in the state is due largely to the system of farming in vogue which allows a great majority of the stock raised on ranches to run at large on the range in the mountains or on the plains a large part of the year, keeping them on the ranch only during the cold months. This system reduces the expense of raising stock to a minimum. Every animal that can be spared from the ranch is thus grazed on lands that cannot be farmed and consequently have a small value. Outside of the dairies there are not a great many cows milked. The total number of cows in the state is about 20,157, according to the 1900 census report. The milk cows and the work horses constitute the ranch live stock during the greater part of the year. Then, too, there are not a great number of cattle fattened in the state and so there is not the demand for hogs to follow the cattle in the feed lots.

A third reason is the lack of information among our farmers of the feeding value of our home-grown grains for

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fattening hogs. Corn is not grown to any extent in Colorado, except for fodder, and it is entirely reasonable that it will never be grown extensively because of existing climatic conditions. There is an occasional farmer that raises some corn each year, but they are mostly in favored localities where the nights are warmer than our average condition. It will follow then that our steers will continue to be shipped to the corn belt states to be fattened, and the demand for hogs to follow cattle in the feed lots will be small.

Will it then pay to raise and fatten hogs for market in Colorado? If it will pay, will it pay better than some occupation to which our farmers have access at present? Let us look first at the products of the farming or ranching communities. In the Cache la Poudre, Big Thompson, St. Vrain and South Platte Valleys, which constitute the irrigated section of northeastern Colorado, alfalfa is the principal product grown. Wheat comes next, with oats and potatoes following in succession. The raising of sugar beets is assuming remarkable proportions and may eclipse some of the former products in acreage and importance. The cultivating and harvesting of these crops occupy the summer months. Lamb feeding is the principal winter occupation and assumes larger and larger proportions each year, as it affords profitable disposition for the immense quantities of alfalfa raised, and earns a large percent for the skill of the feeder and the capital invested. Cattle raising is the chief agricultural industry of the whole state, and together with the raising of horses and sheep, doubtless must ever be foremost, because of the many million acres of semi-arid plains that grow nutritious native grasses, and which do not produce a paying crop under cultivation. Then there is the vast mountain region that supports on its precipitious slopes sleek cattle, horses and sheep. Together these two ranges maintain, according to the last statistics, 1,333,202 cattle; 236,546 horses, and 2,044,814 sheep. As stated before, this stock is kept on the ranches only about two months each year, and it is only those that have the best of care that remain that long where there is shelter and hay. So this class of stock would not interfere with hog raising in the least, and hog raising and lamb feeding would be mutually beneficial. The time spent in caring for a bunch of hogs would not interfere with the farming operations any more than it does in other places.

The one consideration then should be whether capital invested in hogs would yield as good returns as invested elsewhere on the farm. This may be judged, in part

at least, by the results of these experiments. We must decide whether we have forage crops and grains to properly raise and fatten hogs, or whether it would be advisable to ship in such foods.

Unlike lambs, hogs will not consume a large amount of rough forage and make as profitable a gain therefrom, but they must be fed a more concentrated or less bulky ration. The stomach of the sheep holds only 30 to 34 quarts, while the stomach of the hog holds from 7 to 9 quarts. Under our conditions profitable lamb feeding and profitable hog feeding must be different questions carried out along different lines. Lambs naturally fit into our system of farming to use up the surplus alfalfa hay. Unless we can feed home grown products to hogs with profit they will not fit into our conditions in the same way, though our pasture conditions for them are ideal.

ALFALFA FOR PASTURE.

It is essential in raising hogs to have some pasture grass for them. Especially is this true of the brood sows and the young pigs which need not only the green feed but the exercise and sunshine out of doors. Alfalfa fulfills this requirement admirably, as it makes a forage which is perfectly safe for hogs to pasture, is nutritious, palatable, grows early in the spring and late in the fall. Alfalfa produces more green forage per acre than any other forage used for hog pasture in the central west. Colorado is credited with 799,611 acres of this crop. It is essential to every ranch where mixed farming is carried on. Alfalfa is grown to such an extent in the state that any farmer or stockman could spare a few acres for hog pasture. The value of an acre of alfalfa throughout the season for laying on pork has not been reported from any station, but long experience has taught practical hog raisers that a little corn or a small amount of other grain, together with good alfalfa pasture, will give excellent returns. Alfalfa alone seems to supply little more than a maintenance ration, but as such is very valuable.

BEET PULP.

With the growth of the sugar beet industry and the building of factories for the manufacture of beet sugar, within the state, an important by-product, beet pulp, has been added to the list of foods available to stock feeders. Pulp is made by cutting sugar beets up into shreds about one-half the size of an ordinary lead pencil in order to extract the sweet juices from them by allowing the mass of shredded

beet to soak in a constantly moving bath of hot water until the sugar is dissolved out. Thus the pulp comes in contact with no chemicals whatever to impair its healthfulness as a food product. Any unhealthful property that the pulp might have must therefore be laid to outside contamination or other causes, and not to any process in the manufacture of sugar from the beets. After coming out of the hot water bath, the pulp is run into an immense vat or storage silo for future disposition.

The purchase price of pulp in this state is 35 to 50 cents per ton at the factory and a lower price than this is often made to farmers who furnish beets.

Beets produce approximately fifty percent of their weight of pulp, and in some places an amount of pulp is given back corresponding to the amount of beets furnished. Extravagant prices have been paid for pulp in some instances. A note published in one of the eastern farm papers quoted a price per ton obtained for pulp one dollar in excess of the price paid originally for the beets. Where the pulp has to be shipped from the factory for a short distance an additional sum, say fifty cents per ton, would have to be added to the price to pay freight. Then there is the hauling of it from the car, which makes another item of expense of say 25 cents per ton if the distance is two miles or less. This makes the total expense 75 cents per ton plus the price of the pulp at the factory. This would make the total cost, within a reasonable distance of the factory, $1.25 per ton for wet pulp. The loss of water will cause continual shrinkage. The amount of shrinkage cannot be estimated, but will depend largely upon whether the pulp has been pressed at the factory, or whether it is obtained from the discharge pipe or taken from the silo where it has drained for a greater or less length of time.

The palatability of pulp, when properly handled, is unquestioned. Our experience at this Station is that horses, cattle and sheep, and especially such of these as are used to roots, relish pulp and will eat it greedily. Our pure bred sheep that are kept on the College farm broke through the fence repeatedly to get at a pile of pulp. The horses also were especially fond of it, and while the cattle did not appear so greedy they ate it heartily. A little difficulty was encountered in getting some Mexican lambs, with which we were experimenting, to eat the pulp, but in a few weeks time they were consuming a considerable quantity of it. The hogs used in this experiment acted much the same way, not caring for the pulp and almost absolutely refusing to

eat it for some time. The grain fed was mixed with the pulp and in a few days they were eating the mixed pulp and grain greedily.

The low per cent of nutrients in pulp does not give it a very good recommendation as a food. The composition of Colorado pulp as determined by Dr. Headden, compared with alfalfa, runs thus:

	Dry Matter in 100 lbs.	Digestible Nutrients in 100 lbs.		
		Protein.	Carbo-hydrates.	Ether Extract.
Beet Pulp	10.0	0.38	7.36	.02
Alfalfa	91.6	11.00	39.60	1.20

Dr. Headden states that his analyses were made of grated pulp which probably contained a minimum amount of nutrients. The California Experiment Station gives a somewhat higher composition than the foregoing. Analysis quoted from Herbert Myrick's book on "The American Sugar Industry," p. 108.

	Dry Matter.	Digestible Protein.	Digestible Carbohydrates.	Digestible Ether Ext.
Beet Pulp	10.0	1.3	6.7	0.4

Taking our own analysis showing the smallest amount of foods in one ton of beet pulp there are 200 pounds of dry matter, of which 7.6 pounds are digestible protein; 147.2 pounds digestible carbohydrates, and 4 pounds digestible ether extract. In alfalfa there are 1832 pounds of dry matter in one ton, of which 220 pounds of protein are digestible and 792 pounds of carbohydrates are digestible, and there are 24 pounds of digestible ether extract. As alfalfa is worth about four times as much as pulp costs laid down on the farm, we readily see that in the matter of composition the pulp makes a poor showing. This is illustrated in the following table of comparative values:

	Dry Matter in 2000 lbs.	Digestible Nutrients in 2000 lbs.		
		Protein.	Carbo-hydrates.	Ether Extract.
One ton Pulp worth $1.00	200	7.6	147.2	0.4
500 lbs. Alfalfa worth $1.00	458	55.0	198.0	6.0

However the feeding value of pulp may not be definitely determined by the percentage composition because the pulp is not used as a basis food but as a condiment or succulent sauce to increase the appetite and aid digestion, and in that respect it may have a value which would make it profitable to feed under certain conditions. If two or even four pounds of pulp per head each day would help the digestion of the other foods fed, or if in a preliminary feeding

period pulp could be used in a ration to put animals in a condition to fatten readily. then it might have a value even in excess of the \$1.00 or \$1.25 per ton. It has been clearly demonstrated that for fattening hogs the corn cob has a value when ground up with corn, because it lightens the meal in the stomach and thus makes it more digestible. It is not beyond the range of possibility that pulp may serve this same purpose in a region where ear corn is uncommon, and at the same time furnish some nutrients in the ration.

KEEPING QUALITY OF PULP.

There are various methods for the preservation of pulp. In some parts of Utah where rock salt is plentiful, large pits are dug in the ground and quantities of salt are thrown into the pulp when it is being put into this pit, which, it is claimed, makes a splendid silo. When the pulp is exposed to the weather the top layer dries out and the pulp further down forms a thick pasty layer five or six inches deep. This layer excludes the air and keeps the pulp fresh and sweet. During this experiment we had pulp in piles on the ground from the first of January until late in June. It was preserved in an unfermented, or only slightly fermented, condition until the early part of June, when warm weather came on. When it is desirable to keep pulp no longer in the season than this, it is just as well to pile it on the ground. If it is to be kept through the summer, most any form of silo is efficent, and in deep piles it has been known to keep two or three years.

SUGAR BEETS.

A conservative estimate of the sugar beets grown in the state this year (1902) for the factories would be 35,000 acres. This will yield approximately 350,000 tons of sugar beets which, if made into sugar, will give more than 150,000 tons of pulp. Besides this there is a large acreage being grown for feed. Numerous requests have been received by this department asking for information of the feeding value of sugar beets for all kinds of live stock. Reports have come in of feeders paying more for sugar beets than is paid by the factories. Large quantities have been fed the last two years with evidently good results, and in many places feeders have made special arrangements for sugar beets for their stock the coming season.

There is no question about the feeding value of these beets for stock-cattle, sheep and hogs, to maintain health,

thrift and breeding qualities; but their value when used as the basis of a fattening ration is not so well determined. As this is the way they are being used in this state, several experiments with beets were planned to determine whether or not they can be made a part of a fattening ration with profit. Many farmers have reported feeding them alone to hogs with good results, but the chemical composition of sugar beets is prima facia evidence that hogs cannot make good and profitable gains when fed on beets alone, because there is not sustenance enough in the amount of them a hog can eat and digest, to do much more than maintain the animal at a constant weight. According to feeding standards, a hog weighing 200 pounds to make the best gain, needs digestible nutrients as shown in the following table:

	Dry Matter.	Digestible Protein.	Digestible Carbohydrates.	Digestible Ether Ext.
Standard for 200 lb. hog	6.4 lbs.	0.8 lbs.	4.8 lbs.	0.1 lbs.

CHEMICAL COMPOSITION OF SUGAR BEETS.—POUNDS IN 100.

Dry Matter.	Digestible Protein.	Digestible Carbohydrates.	Digestible Ether Extract.
20.0	1.135	16.007	0.051.

In 25 pounds of sugar beets there would be digestible nutrients as follows:

	Dry Matter.	Digestible Protein.	Digestible Carbohydrates.	Digestible Ether Extract.
Sugar Beets 25 lbs.	5.0	0.284	4.002	0.013

Twelve and a half pounds was all we could get a hundred-pound hog to eat in one day during the experiment. By comparison it will be seen how far short of the standard 25 pounds of beets would be for a two hundred-pound hog, were it possible to get him to eat that amount. However, if beets could be made to take the place of some grain in the fattening ration supplying them might be of advantage.

HOME GROWN GRAIN VS. CORN.

By home grown grains is meant wheat, barley, oats, and such other small grains as are grown in Colorado. It would be hard to give an intelligent estimate of the amount of corn that is annually shipped into the state for feeding purposes. Feeders have frequently resorted to home grown grains during periods of high prices of corn. It is a common custom to trade wheat and barley off for corn. Even this last winter when wheat was $1.00 per hundred pounds, and at one time as low as 90 cents per hundred, feeders

hauled in wheat and took home corn at $1.30 per hundred. Barley was selling at about the same figure as wheat. The acreage of wheat as given in the government reports for 1900, was estimated at 318,899 acres; barley, 12,672 acres, oats, 99,768 acres; rye, 2,350 acres. The combined yield of these four grains for that year approximated 11,000,000 bushels.

It is a well known fact that under irrigation the small grains produce plumper, larger kernels giving greater weight per bushel, and that the chemical composition differs widely from that of grains grown under rainfall conditions. Repeated feeding experiments in other states have shown wheat to be fully equal to corn for fattening hogs, and barley to be worth about 8 percent less than wheat or corn Prof. W. W. Cooke, formerly of this Station, made an extensive and exhaustive experiment comparing barley and corn, both whole and ground, for fattening hogs, with the following results:

	No. Tests.	Av. Weight at Beginning.	Average Daily Gain.	Average Daily Feed.		Food per lb. of Growth.	
		lbs.	lbs.	Grain lbs.	Skim Milk qts.	Grain lbs.	Skim Milk qts.
Whole Corn..	6	71	0.39	2.0	0.7	7.0	1.1
Ground Corn	5	60	0.46	2.4	1.0	5.4	1.1
Whole Bald Barley...........	8	88	0.58	2.3	1.2	5.0	1.3
Ground Bald Barley	5	67	0.74	2.4	0.8	3.6	0.8
Whole Common Barley.......	4	68	0.49	2.3	0.5	5.4	0.7
Ground Common Barley......	4	47	0.70	2.4	1.1	4.3	1.1
Ground Corn and Barley	4	50	0.77	2.1	1.0	4.1	0.8

This experiment shows the superiority of irrigation grown barley over rainfall corn and thus over rainfall grown barley.

The average price of corn in Colorado for the past ten years has been 80.5 cents per hundred pounds; wheat 99.5 cents; barley 55.1 cents. An average for wheat and barley of 77.3 cents, or 3.2 cents per hundred less than corn. If

then, our home grown grains are worth less money right on our farms than corn in town, and in turn either of them singly will produce more pork per pound than will corn, and when fed mixed are far superior to corn, have we not the solution of the problem of supplying concentrates which will profitably fatten hogs? (In this connection special attention is called to Summary of Lot IV. in the 1902 Experiment, page 22). Together with the alfalfa for forage and the sugar beets and their by-products for roughage, Colorado should become a factor in the production of pork.

OBJECT OF EXPERIMENT IN 1902.

To test the value of pulp and sugar beets when fed with grain; the value of sugar beets alone; and these three compared with corn, wheat and barley, was the purpose of this experiment. It is really a comparison of home grown foods vs. corn and is a continuance of experiments previously carried out with both swine and sheep. It is also important at this time to be able to give something definite about the value of sugar beets and pulp for all classes of stock. There will be in excess of 150,000 tons of beet pulp available for feeding this fall and winter. To be able to utilize this for wintering or fattening stock would add vastly to the live stock industry. So large a subject is this feeding of pulp that this bulletin does not attempt to treat more than partially the utility of pulp for fattening swine.

PLAN OF EXPERIMENT.

Twenty shoats were divided into five lots of four each. Care was taken in selecting the individuals for each lot, that each pen should be as representative as possible for the entire number. Each lot had the same sized pen in the piggery and each had access to the small yards adjoining.

Pigs in Pen I. were fed sugar beets alone.
Pigs in Pen II. were fed beet pulp and ground wheat and barley.
Pigs in Pen III. had shelled corn.
Pigs in Pen IV. were given ground wheat and barley.
Pigs in Pen V. were given sugar beets, ground wheat and barley.

For the pigs in Pen I. the sugar beets were chopped into small pieces and the pigs were given all that they would eat of them. Fresh, clean water was supplied twice daily at feeding time. Besides this, the shoats had access to nothing but the straw used for bedding, except an occasional small quantity of ashes or coal which was supplied to all pens alike. These pigs were fed to see just what hogs

would do on sugar beets alone, because some of our farmers had been doing this and we wished accurate data for a check.

The hogs in Pen II. were fed a large quantity of pulp, especially during the first part of the experiment. It was necessary to mix the grain with the pulp to get the pigs to eat the pulp.

The hogs in Pen III. were fed shelled corn alone, having access to nothing else but the straw used for bedding, besides plenty of water and some coal and ashes. It might have been better to have fed the corn ground, especially as the pigs were young and growing rapidly, and again because ground wheat and barley were fed.

The hogs in Pen IV. were fed equal parts of ground wheat and barley, for comparison with Pen III.

The pigs in Pen V. were fed in all respects like those in Pen II., except that sugar beets were substituted for the pulp. In the results from these two pens, we have a comparison of the value of pulp and the value of sugar beets when fed with grain. Pens II. and V. also may be compared with Pen IV., thus giving the advantage, if any, of feeding pulp or sugar beets with grain for fattening hogs.

The feed given was carefully weighed and any remaining uneaten until the time of the next feeding was weighed back. The hogs were ear-tagged and weighed separately once a week, thus giving the individual differences of those in the same pen. Additional notes were kept as to the general condition of the individual hogs in each lot so that, at the end of the experiment, it would be known whether or not the best results possible had been attained under the conditions. We have been assisted in these experiments by Mr. Fred Bishopp and Mr. W. B. Smith, senior agricultural students, who carried out the feeding as planned and aided in keeping the records.

KIND OF HOGS FED.

The hogs used in this experiment were obtained from the slaughter house yards of wholesale butchers within the city. From appearances the hogs were grade Poland Chinas and Berkshires. From the information that could be gleaned from those in charge, the pigs had been bought from different farmers in the vicinity and had been at the yards only a short time before we obtained possession of them. They were only common scrub shoats and did not show that any special care had been taken of them. They were probably late spring pigs and approximately eight

months of age. Their average weight was close to 100 pounds at the time they were put on the experiment. It was necessary to pay 6 cents a pound which was too high a price for pigs of their weight and breeding.

PULP FED.

The pulp fed was obtained from the Loveland factory of the Great Western Beet Sugar company, whose manager, Mr. A. V. Officer, courteously supplied us a carload for experimental use. Laid down at the College farm it cost us approximately $1.00 per ton. This pulp was piled out on the ground about January 1, 1902, and was used as it was needed for feeding The ground on which it was piled had good drainage and the moisture from the pulp drained away as it seeped out. Thus, in a few days time, the pulp was in nice condition, comparatively dry, and was preserved in an unfermented condition much better than some other piles of pulp which we had placed where the moisture did not drain away.

BEETS FED.

The sugar beets used in this experiment were grown upon the College farm, put in a root cellar after digging, and taken out as there was need of them. During the latter days of the experiment, the supply of sugar beets was exhausted and a stock beet was substituted in their stead. They were fed stock beets only about two weeks, the time being so short the final result was probably not changed by the substitution. The beets fed were figured at $4 per ton. This would be equal to from $4.50 to $5 per ton for beets delivered at the factory; first because of the expense of hauling or shipping them to the factory, and second the work and expense of trimming the beets, which would amount to at least 50c per ton.

GRAIN FED.

The wheat and barley fed were also grown upon the College farm. The wheat was of the common Defiance variety and was grown in a field producing 34 bushels per acre. The barley fed was of the common hulled variety and was grown in a field which produced 25 bushels per acre. Together they were rated at $1 per hundred pounds, which we think is not too low an estimate to put upon these grains, as there was considerable time during the late fall when either wheat or barley could have been purchased below that mark:

EXPERIMENT OF 1902.

SUGAR BEET PRODUCTS, AND HOME GROWN GRAINS.

On February 19th, twenty hogs were weighed and put upon the experiment. Previous to this time they had been kept together on the same ration for one week. In their drinking water they had been given a weak solution of sulphuric acid to free them from intestinal worms. They had also been sprayed for lice with 3 percent solution of Zenoleum. The pigs at this time were in a healthy, growing condition, and as will be seen in the summary, they averaged approximately 100 pounds each.

Those in Pen I. did not take very readidly to the sugar beets and it was evident that they had never been used to a ration with roots in it, but they very soon began to eat the beets heartily.

Those in Pen II. would not touch the pulp fed them for several days. From February 19th to 22d inclusive, the four pigs in this lot were given only 40 pounds of pulp, and eight pounds of this were weighed back as orts which they did not eat.

The pigs in Pens III. and IV. took hold of the food given them readily, as also did those in Pen V., fed with the wheat and barley in addition to the beets. They ate the sugar beets, but apparently did not relish them at first.

Table I. which follows, gives the amount of food fed in periods of one week each for each pen, also the total amount of food eaten by the pigs in each pen. On May 30th, the hogs in Pens I., II., and two from Pen III., were slaughtered. Those remaining were slaughtered on June 6th.

Table I. is of interest as it shows the consumption of food week by week. The pigs were given approximately all they would eat. The pigs in Pen I. ate an increasing amount of sugar beets up to May 3d, within four weeks of the end of the experiment. They seemingly had eaten so many beets during the week ending May 3d that they became tired of them and would not again consume as large amounts.

The pulp fed to the pigs in Pen II. was increased until March 22d, and then decreased because the grain was increased for finishing the pigs and it was thought advisable to cut down the large amount of succulent food.

TABLE I.

FOOD EATEN.

Date.	Pen I	Pen II		Pen III	Pen IV	Pen V	
	Sugar Beets.	Wheat and Barley.	Pulp.	Corn.	Wheat and Barley.	Wheat and Barley.	Sugar Beets.
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
February 19-22	117	35	40	48	45	31	28
February 22-March 1	230	72	123	89	102	74	57
March 1-8	239	70	232	70	123	75	70
March 8-15	280	70	285	79	131	98	80
March 15-22	287	79	294	98	140	98	94
March 22-29	302	90	291	112	149	98	116
March 29-April 5	308	84	251	112	154	98	126
April 5-12	308	116	168	112	154	98	126
April 12-19	324	126	168	112	154	118	126
April 19-26	324	126	168	112	154	126	134
April 26-May 3	348	126	168	112	154	126	130
May 3-10	324	126	172	112	154	126	140
May 10-17	264	126	172	112	154	130	100
May 17-24	182	126	172	112	154	138	80
May 24-30	270	90	120	96	154	126	128
To June 4	...	...	...	44	110	104	20
Totals	4107	1372	2824	1734	2188	1664	1565

The pigs in Pen III. on corn, and those in Pen IV. on wheat and barley, practically consumed increasing amounts of food up to the end of the experiment and the respective lots practically consumed the same amounts of grain each week for the last nine full weeks. The last four weeks the amount of sugar beets given to those in Pen V. was reduced, but the grain was increased as they would consume it.

Table II. page 17 gives the individual weights each week for all the pigs. The last column gives the total gain of each pig during the experiment and the first column the ear-tag number. Food given each lot is given in Table I. The last weight of each pig, taken May 30th or June 6th, was made after they had been off feed for 24 hours before slaughter, and represents the gain during the last week, less the shrinkage. Pig No. 80, in Pen II, was found to be in pig soon after the feeding began and was left with the lot to see what the final effect would be. She dropped a litter of three pigs March 29th and killed all of them. She was left on feed and made a larger total gain than any other pig in that pen.

Table III. gives the total weekly gains made by the four pigs in each pen and the last column gives the total gain of each lot for the whole period, less the 24 hours shrinkage before slaughter. The minus sign before a number indicates a loss of weight. There is much variation in the gains made week by week, the differences being especially noticeable in Pen I., fed on sugar beets, and in Pen II., given pulp and grain. The gains did not vary so much with the grain rations.

TABLE III.

EXPERIMENT NO. I.—SWINE FEEDING. POUNDS GAIN PER WEEK.

	February 22	March 1	March 8	March 15	March 22	March 29	April 5	April 12	April 19	April 26	May 3	May 10	May 17	May 24	May 30	June 4	Total Gain
Pen I.	[illegible]	[illegible]	6	6	18	10	6	4	6	4	-4	19	-11	25	-10		67
Pen II.	22	8	32	6	62	-1	29	10	39	33	41	40	0	20	11		352
Pen III.	30	7	-12	30	32	5	35	12	26	21	31	16	16	7	22	7	285
Pen IV.	29	24	12	51	49	11	55	29	33	29	49	47	37	14	33	-21	481
Pen V.	16	19	16	26	25	25	34	24	32	32	36	38	39	22	13	5	392

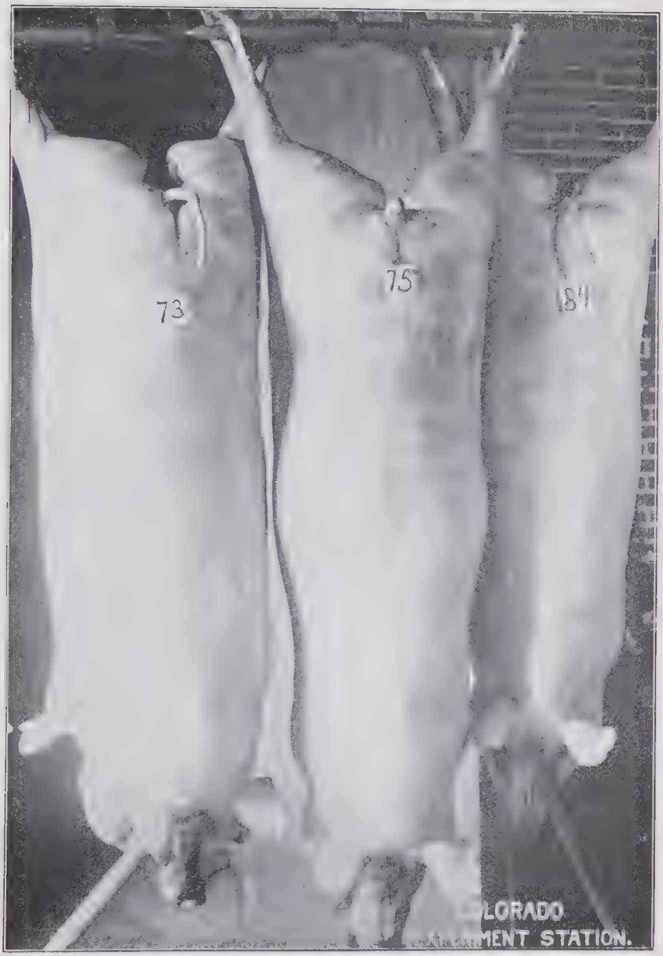

PLATE I.

Representative Carcasses from Lots III, IV and V.
No. 84, Fed Corn.
No. 75, Fed Wheat, Barley and Sugar Beets.
No. 73, Fed Wheat and Barley.

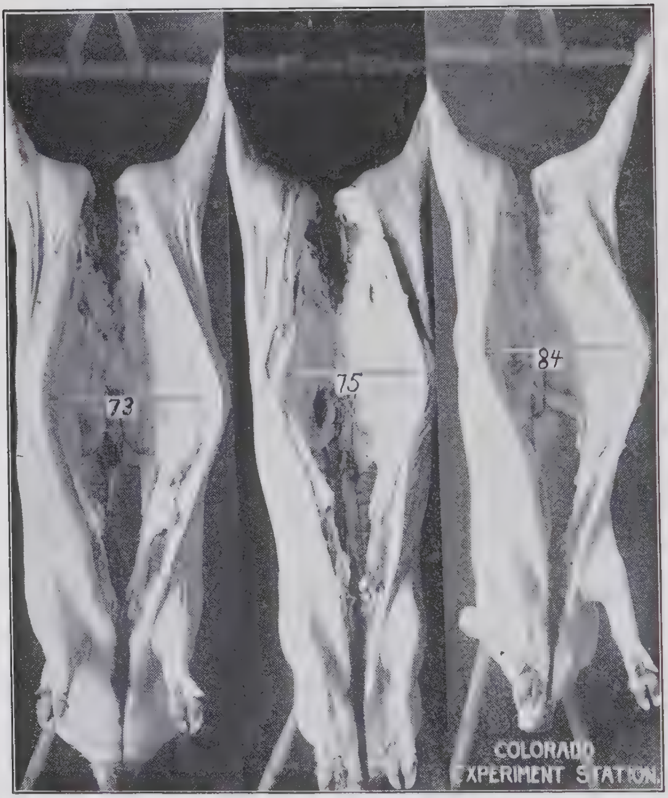

PLATE II.

Representative Carcasses from Lots III, IV and V.
No. 84, Fed Corn.
No. 75, Fed Wheat, Barley and Sugar Beets.
No. 73, Fed Wheat and Barley.

TABLE II.

		February 19	February 22	March 1	March 8	March 15	March 22	March 29	April 5	April 12	April 19	April 26	May 3	May 10	May 17	May 24	May 30	June 6	Total
	No. Tag	lb	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Pen I	574	110	117	124	112	114	115	115	116	118	119	119	124	122	121	131	128		18
	582	90	100	91	94	94	99	97	96	96	96	99	102	100	97	104	102		12
	181	106	110	108	110	112	118	115	118	118	121	122	124	127	125	130	127		21
	562	95	99	98	99	101	107	102	105	107	109	109	95	115	110	113	111		16
Pen II	80	107	118	121	128	140	158		148	154	163	172	183	191	196	204	207		100
	585	90	96	100	106	108	118	115	129	125	133	139	149	157	162	162	165		75
	577	95	96	95	108	100	118	121	134	140	153	162	174	181	183	190	191		96
	81	95	99	101	106	106	122	121	123	135	144	153	161	179	167	172	176		81
Pen III	77	110	117	117	114	124	131	131	141	145	149	156	159	169	173	174	178		68
	78	90	96	98	96	103	112	116	122	126	133	139	149	147	150	154	159	162	72
	79	90	91	94	91	97	105	108	117	120	128	134	142	147	150	154	159		69
	84	90	106	108	104	111	119	117	127	128	135	137	147	150	156	154	162	166	76
Pen IV.	73	115	120	123	130	143	155	158	170	180	182	193	202	219	230	239	249	241	126
	70	100	109	117	114	127	140	146	157	165	176	180	193	201	210	213	221	218	118
	74	98	104	114	122	132	143	149	166	173	181	194	209	223	230	236	244	239	141
	83	65	74	77	77	92	105	101	116	120	132	133	145	153	163	159	166	161	96
Pen V.	75	108	118	124	126	137	145	149	158	164	176	185	193	206	215	219	225	228	110
	87	95	93	97	99	105	115	116	125	131	139	148	155	161	173	179	183	184	89
	72	95	97	105	109	109	109	123	131	135	144	150	156	159	175	179	175	179	84
	85	105	111	112	120	129	136	142	150	158	161	169	184	200	202	210	217	204	99

FOOD EATEN DAILY.

The average amounts of food eaten per day throughout the experiment for each hog in each pen were as follows:

TABLE IV.

FOOD CONSUMED DURING EXPERIMENT.

	No. of Hogs.	Days Fed.	Average Food per Hog.				Average Weight and Gain per Hog.		
			Corn	Wheat and Barley.	Sugar Beets	Pulp.	Beginning.	End.	Gain.
			lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Pen I	4	99			1026.75		100.25	117.00	16.75
Pen II	4	99		343.00		706.00	96.75	184.75	88.00
Pen III	4	101	383.50				95.00	166.25	71.25
Pen IV	4	104		546.50			94.50	214.75	120.25
Pen V	4	104		416.00	391.25		100.75	198.75	98.00

DISCUSSION OF RESULTS.

In Table IV. is given the amount of food consumed, stated in averages for each animal in the different lots, and the average weight and gain of the four pigs in each pen at the beginning and end of the experiment.

TABLE V.

FOOD EATEN DAILY.

	Average Food Per Day.				Gain per Head per Day.
	Sugar Beets.	Wheat and Barley.	Pulp.	Corn.	
	lbs.	lbs.	lbs.	lbs.	lbs.
Pen I	10.37				0 17
Pen II		3.46	7.10		0.89
Pen III				3.80	0.70
Pen IV		5.25			1.16
Pen V	3.76	4.00			0.94

Table V. gives the average food per head eaten daily. The pigs in Pen I. ate 1,026.75 pounds of sugar beets, or 10.37 pounds per day, on which they made average total gains of

16.75 pounds. The pigs in pen V. ate 391.25 pounds of sugar beets, or 3.76 pounds per day, and 416 pounds of grain, or 4 pounds per day, or a total of 807.25 pounds of food, making an average gain of 88 pounds.

The food given to Pen I. did little more than maintain the original weight of the animals, while in Pen V. one-third the amount of beets in addition to four pounds of grain per day produced substantial gains. The pigs in Pen II. ate 706 pounds of beet pulp, or 7 pounds per day, and 343 pounds of grain, or 3.64 pounds per day. The total amount of feed consumed by each pig was 1049 pounds, a little more in weight than was eaten by Pen I. The total gain was 88 pounds, or only ten pounds less than that made in Pen V. on 63 pounds more grain and a little more than one-half the weight of beets, but the ration in Pen V. is appreciably greater in cost than that given in Pen II.

Pens III. and IV. give us a comparison of the amounts of corn and wheat and barley consumed, with their respective gains. The pigs in Pen III. ate 383.5 pounds of corn, or 3.8 pounds per day, making average gains of 71.25 pounds. In Pen IV. each pig ate 546.5 pounds of grain (equal parts wheat and barley) or 5.25 pounds per day, making average gains of 120.25 pounds.

Wheat and barley is shown to have had a decided advantage over corn in this experiment. When the chemical composition of corn and wheat and barley is taken into account, these results are not surprising. In corn there is not sufficient digestible protein,—or the muscle, blood and bone-building element—in proportion to the carbohydrates—or fat and heat-producing element—for the most economic gain. This porportion of protein to carbohydrates is called "nutritive ratio." For fattening hogs this nutritive ratio should be about 1 to 7 (one part protein to seven carbohydrates), to obtain the best results. In corn this ratio is 1 to 9.7, while in equal parts wheat and barley it is 1 to 7.5. It is usual to feed some substance richer in nitrogen with corn in order to make the ration nearer the correct standard. The fact that wheat and barley mixed in equal parts furnishes a ratio so nearly correct may account for their greater palatability, making the pigs consume so much larger quantities of these grains than they would eat of corn alone, and as would be expected, they made greater gains.

COST AND PROFIT.

The true measure of the efficiency of a food ration for fattening stock is the value of the resulting product after

the cost has been deducted. In Table VI. will be found a comparison of the cost of the food consumed by each animal and the first cost of the feeders and the profit at selling prices of six cents and seven cents per pound. Six cents per pound for the feeders was too high a price in the beginning. Seven cents per pound at the close of the experiment was not too high a price, so our statement of profit based on this buying and selling price is a conservative one. Feeding in small lots and experimentally as we did, makes it impossible to state fairly the cost of the labor used, but this is not necessary in order to make a true comparison of the different foods under investigation. The farmer who has had any experience in feeding swine can estimate this item for himself. The feeding is usually done at a season when the farmer's time, or that of his men, is not considered so valuable, and the pig feeding comes in after hours any way as chores. This is not an attempt to slight or ignore the question of labor at all, for it is a real one, but every farmer must estimate this item of expense for himself. There is no attempt made in this bulletin to show the cost of raising pigs up to the time they weigh 100 pounds. They were bought at 6 cents per pound and the results are figured from that basis. A large profit would be realized on pigs grown to that weight which could be sold at six cents per pound.

The total cost of the food eaten by pigs in Pen I. averaged $2.05. The total profit on each head at 7 cents was 13 cents, and at 6 cents there was a loss of $1.04 on each. Although the cost of the food was small, the profits were unsatisfactory because the gain in weight was so small.

Pen V., with a total cost of food of $4.94 per hog, made a total profit of $.95 at 6 cents per pound, and at 7 cents per pound a total profit of $2.93. The pigs in Pen II. ate $3.78 worth of food per hog and made a total profit of $1.50 when figured at 6 cents per pound, and $3.35 at 7 cents per pound.

Pen II did not make as large a total gain by ten pounds per hog as Pen V. (see Table VI), but they did not consume as much grain by 73 pounds for each animal. While the pigs in Pen II. ate more than twice the amount of pulp, the cost of the pulp given each hog was not one-half as much as the cost of the beets given to Pen V. In the total profit then, the extra gain in live weight made by Pen V. was more than balanced by the cheapness of the ration fed to Pen II.

Pen III., with $4.98 charged against each animal for

corn, made a total profit of $.95 per hog, figured at 7 cents per pound, and at 6 cents they made a loss of $.71. The value of the food consumed by Pen IV. was $5.46 per hog. The total profit at 6 cents was $1.75 each, and $3.90 at 7 cents.

TABLE VI.

COST OF FOOD AND TOTAL PROFIT.

	Average Cost of Food Eaten.				Average Total Cost Food Eaten.	First Cost @ 6 cts per lb.	Average Total Profit.	
	Corn @ $1.30.	Wheat and Barley @ $1.00.	Sugar Beets @ 20 cts cwt.	Pulp @ 5 cts cwt.			@ 6 cts per lb.	@ 7 cts per lb.
Pen I..........			$2.05		$2.05	$6.01	—$1.04	$0.13
Pen II.........		$3.43		$0.35	3.78	5.80	1.50	3.35
Pen III........	$4.98				4.98	5.70	—0.71	0.95
Pen IV........		5.46			5.46	5.67	1.75	3.90
Pen V.........		4.16	0.78		4.94	6.04	0.96	2.93

POUNDS OF FOOD AND COST FOR ONE POUND OF GAIN.

Table VII. gives the cost of the average amount of food eaten by each pig, at the current prices for the feeds used, and the actual cost of each pound of gain made during the fattening period. In next to the last column of the table is given the final cost for each pound of dressed pork which shows the amount per pound which would have to be received for the dressed meat in order to merely balance the cost of the food consumed.

TABLE VII.

FOOD FOR ONE POUND GAIN.

	Average Food for One Pound Gain.				Average Cost per pound of Gain.	Average Cost per Pound of Dressed Pork.	Percent of Dressed Meat.
	Corn	Wheat and Barley.	Sugar Beets.	Pulp.			
	lbs.	lbs.	lbs.	lbs.	cts.	cts.	%
Pen I.....			61.3		12.3	8.9	77
Pen II....................		3.9		8.	4.3	6.5	80
Pen III..................	5.4				7.	8.	80
Pen IV..................		4.5			4.5	6.1	84
Pen V....................		4.2	4.		5.	6.8	84

While sugar beets cost less per pound than any other food, except pulp, it took 61.3 pounds of beets for each pound of gain made at a cost of over twelve cents. There was a comparatively large amount of waste in the beet fed lot, as they dressed only 77 percent of the live weight.

The pigs in Pen II. ate 3.9 pounds of grain and 8 pounds of beet pulp for each pound of gain. This made the cost of each pound of gain 4.3 cents and the cost of each pound of dressed pork 6.5 cents. They dressed 80 percent of the live weight which is a little better than the beet fed lot and is the same as the corn fed lot.

The pigs in Pen V. which were given the same kind of grain as the pulp fed lot in Pen II. and sugar beets instead of pulp, ate just a little more grain, 4.2 pounds, and one-half the amount of beets, or 4 pounds, compared with 8 pounds of pulp in Pen II. However, each pound of gain cost 5 cents in the beet fed lot and the dressed pork cost 6.8 cents per pound. In this trial, then, the pulp gave a better return in dollars and cents than the sugar beets. It is believed the results would have been still more favorable to the pulp if we had fed only one-half as much, or three and one-half pounds instead of seven pounds, which was consumed per day. The beet fed lot actually ate three and three-fourths pounds of beets per day.

The pigs in Pen III. ate 5.4 pounds of corn for each pound of gain, making the cost of each pound of gain 7 cents, or 8 cents per pound for dressed pork.

The pigs in Pen IV. ate only 4.5 pounds of grain composed of equal parts of wheat and barley for each pound of gain, at a cost of 4.5 cents, or of 6.1 cents for each pound of dressed pork. These pigs grew better and dressed better than those fed on corn alone. (See illustration.) This shows that one pound of wheat and barley was equal to 1.2 pounds of corn for making gains, where the corn is fed alone. But since corn cost $1.30 per hundred pounds while the wheat and barley cost only $1.00 per hundred pounds, there is even greater difference in the respective values of the dressed pork produced. If wheat and barley were worth $1.00, then in the light of this experiment the farmer could not afford to pay more than 83.3 cents for corn if he contemplated feeding it alone to swine as is usual. Instead of that, many farmers paid 46 cents to over 50 cents per hundred more for corn than it was worth to them and even sold their other grains to enable them to do it.

Comparing the values of pulp with grain in Pens II. and IV., we see that eight pounds of pulp in Pen II. was made

to take the place of 0.6 pounds of grain in Pen IV. This would give the pulp a value of $1.50 per ton when wheat and barley were worth $1.00 per hundred pounds. It was noticed that the pigs given pulp and beets in Pens II. and V. made much larger growth of frame than those in the other pens. This is nicely shown in the photograph here reproduced, of the representative pigs of Pens III., IV. and V., and indicates that such ration given to young pigs during the first feeding period may produce larger ultimate gains and have a greater value than is here indicated where they were also used in the last fattening period.

Comparing the foods given to pigs in Pens IV. and V., it is evident that 4 pounds of sugar beets in Pen V. took the place of 0.3 pounds of grain in Pen IV. This shows the sugar beets to have a value of $1.50 per ton when mixed with grain for pig feeding, or exactly the same value which we obtained for the pulp. It is not unlikely that different values might have been obtained if different proportions of these foods were given, but we would feel safe in advising any farmer not to pay $4.50 or $5.00 per ton for beets for feeding to swine. It is altogether probable that the beets were more valuable than this for sheep and cattle which naturally require a more bulky ration than hogs can profitably use. A bulletin reporting experiments to show the value of beets and pulp when fed to cows has been published, and another reporting experiments with lambs is now ready for press. These publications should be consulted by intending feeders.

PIG FEEDING EXPERIMENTS OF 1900-1901.

ADDING ROUGHAGE OR ROOTS TO A RATION.

An experiment to indicate whether dry alfalfa roughage could be given a place in a ration for swine, was begun on December 1st, 1900. Nine Berkshire pigs were divided into three lots of three each and fed rations of mixed grain, mixed grain and dry alfalfa hay, and mixed grain and sugar beets. The mixed grain consisted approximately of two parts of corn and one of barley. The pigs would not eat the dry alfalfa at first, but they were made to eat it by chopping the hay rather fine and mixing with barley slop.

The pigs were thrifty Berkshires raised on the College farm and were given a value of 4 cents per pound at the beginning of the experiment. The corn was worth 80 cents per hundred pounds and the ground barley $1.05 per hundred pounds. The pigs were fed 97 days and their value is given at five cents per pound live weight at the end of the fattening period.

Table VIII. gives the kinds of food eaten, the average amount of each food consumed by each pig in the ninety-seven days, the live weight at the beginning and end of the experiment, and the average dressed weight.

TABLE VIII.

AVERAGE FOOD, WEIGHT AND GAIN PER HEAD.

	Average Food Eaten.				Average Weight.			Percent Dressed Weight.
	Corn.	Barley.	Sugar Beets.	Alfalfa.	At Beginning.	At End.	Gain.	
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	%
Pen I.	40[illegible].50	1[illegible]0.70		55.30	162.20	272.30	101.10	86.10
Pen II.........	381.30	173.50			154.70	259.70	105.00	87.40
Pen III........	350.30	184.30	99.30		148.30	244.70	96.40	87.10

In addition to their grain ration the pigs in Pen I. consumed an average of 55.3 pounds of dry alfalfa hay, a little more than one-half pound per day. They made the best gain but did not dress quite as well as the pigs in the other pens. Those in Pen III. ate approximately one pound of sugar beets apiece per day in addition to the grain ration, but they made the poorest gains.

In Table IX. is given the average food eaten for each pound of gain produced, the average gains made, and the comparative cost and profit. In Pen I. it took 5.44 pounds of grain and .40 pounds of alfalfa to make a pound of gain, and while the pigs in this lot made the best gains on account of the food eaten, it was at a slightly greater cost than where grain was fed alone in Pen II. With the corn and barley mixture it seems that it took a large amount of grain for each pound of gain, not making as good a showing as did wheat and barley in other experiments. While only a small amount of sugar beets was eaten by the pigs in Pen III., adding beets to the ration seemed to produce no beneficial effect. The pigs made smaller gains at greater expense that either of the other lots.

TABLE IX.

FOOD PER POUND OF GAIN, COST AND PROFIT.

	Average Food for One Pound Gain.				Gain per Head per Day.	Cost per Pound of Gain.	Aver'ge Cost of Food Eaten.	Aver'ge First Cost of Hogs @ 4 cts.	Aver'ge Total Profit @ 5 cts.	Aver'ge Cost per lb. of Dress'd Pork.
	Corn.	Barley.	Sugar Beets.	Alfalfa.						
	lbs.	lbs.	lbs.	lbs.	lbs.	cts.	$	$	$	cts.
Pen I......	3.72	1.72		0.49	1.13	4.9	5.40	6.49	1.73	5.10
Pen II.....	3.63	1.65			1.08	4.6	4.86	6.18	1.94	4.90
Pen III....	3.64	1.91	1.03		.99	5.2	5.04	5.93	1.26	5.30

SWINE FEEDING EXPERIMENT OF 1901.

An experiment planned to test the value of shorts when fed with corn and to compare the value of a ration of corn with a combination of wheat, oats and barley with the value of a ration of shorts fed in a like combination. The feeding was done from March 23d to May 31, 1901. Eleven pure bred Berkshire pigs were used in this experiment, averaging about five months of age. The trial was conducted similar in all respects to the other experiments reported in this bulletin. The following foods were fed:

Pen I.—Corn.

Pen II.—Corn and shorts.

Pen III.—Shorts, wheat, oats and barley fed in rotation. Shorts with wheat and oats one day, and with wheat and barley the next, oats and barley the third day and so on.

Pen IV.—Corn, wheat, oats and barley. The corn rotated with two other grains as indicated for pigs in Pen III.

In Pen I. there were two pigs averaging 164.5 pounds. They were two months older than the remaining ones used

in the experiment and weighed a little over sixty pounds over the average in the other pens. The three pigs in each of the remaining pens were quite evenly divided as to age, size, etc.

The following prices were charged in computing the results of the experiment:

Corn, 83 cents per cwt.
Shorts, 75 cents per cwt.
Wheat, 95 cents per cwt.
Oats, $1.20 per cwt.
Barley, $1.20 per cwt.

Table X. gives the average food eaten by each animal in the respective pens, the average weight and gain of same, and the percent each dressed.

TABLE X.

AVERAGE FOOD, WEIGHT AND GAIN PER HEAD.

	Average Food Eaten.					Average Weight.			Percent Dressed Weight.
	Corn.	Shorts.	Wheat.	Oats.	Barley.	At Beginning.	At End.	Gain.	
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	
Pen I.	423.25					164.50	230.00	65.50	78.60
Pen II.	227.00	221.66				104.00	177.60	73.30	77.40
Pen III.		226.50	76.50	73.60	75.50	112.50	188.20	88.20	81.60
Pen IV.	208.60		72.30	68.50	68.30	98.00	185.30	85.60	79.20

TABLE XI.

FOOD FOR ONE POUND GAIN, COST AND PROFIT.

	Average Food for One Pound of Gain.					Gain per head per day	Cost per pound of grain.	Av. cost of food eaten.	Av. 1st cost of hogs @ 4 cts.	Av. total profit @ 5 cts.	Av. cost per lb. of dressed pork
	Corn.	Shorts.	Wheat.	Oats.	Barley.						
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	cts.	$	$	$	cts.
Pen I.	6.43					.98	5.30	3.51	6.58	1.41	4.03
Pen II.	3.08	3.01				1.11	4.80	3.54	4.16	1.18	4.33
Pen III.		2.61	0.88	0.85	0.87	1.31	4.70	4.22	4.50	0.69	4.20
Pen IV.	2.43		0.84	0.80	0.80	1.27	4.70	4.06	3.92	1.19	4.35

Table XI. gives the details of the food eaten for each pound of gain and cost and the profit. The results corres-

pond with those reported on other experiments in this bulletin, in showing that corn alone is not a balanced ration and does not produce the gains that result from feeding other grains with or without corn. This is not so apparent at first from this table as it is after carefully studying the conditions and results.

The pigs in Pen I. were older and larger than those in the other pens. It took 6.43 pounds of corn to produce a pound of gain and their average gain per day was only .98 pounds, compared with much larger gains in the other pens. The cost per pound of gain is high, but the apparent profit and cost per pound of dressed meat is low. This is because they were 64 pounds heavier than the other pigs and at the increase of one cent per pound this weight makes the apparent profit 64 cents higher that it should be when compared with the smaller pigs in the other pens. The real profit in such comparison would be 97 cents instead of $1.41 as actually shown in the table. The cost of one pound of dressed meat figured on the basis of these smaller 100 pound pigs in the other lots, would be 5.77 cents instead of 4.03 cents, and the corn ration would be the most expensive one in this series. This shows the fallacy of figuring all of the pigs at the same price at the beginning of the experiment, regardless of size and age, and illustrates the advantage of selecting larger animals for feeding. With this understanding it appears that mixed grain was superior in every case to corn alone.

The gains per day increased with the increase in the variety of food eaten, and the amount of grain for each pound of gain decreased with the same condition. In Pen I. it took 6.43 pounds of corn for each pound of gain; in Pen II. 6.09 pounds of corn and shorts per pound of gain; in Pen III. 5.31 pounds of mixed grain per pound of gain. In Pen IV. 4.87 pounds mixed grain per pound of gain. Comparing Pens III. and IV. gives an idea of the comparative value of corn and wheat shorts. It took more shorts with other grains in Pen III. to produce a pound of gain than it did corn with other grains in Pen IV. and although the shorts were figured at a less price than corn, the total profit from the pen is less than—approximately one-half—that in Pen IV.

It is likely that the ration given in Pen III is as much too narrow as the corn ration in Pen I. is too wide. The nutritive ratio of corn is about 1:9.4, and of the ratio in Pen III. is 1:5.9. The nutritive ratio called for in the German feeding standard for fattening hogs is 1:7. The nutritive

ratio of the ration given Pen II. is 1:6.3 and that supplied Pen IV. is 1:8.1. The best gains, and for the least amount of food, were made in Pen IV. This study is interesting when compared with the wheat and barley ration fed in the first experiment reported in this bulletin. Equal parts of wheat and barley have a nutritive ratio very near the German standard and have produced the best results for us. Other factors probably influence the effect of a ration as much as will small differences in the ratio. The cost and profit is influenced by the prices of the different grains so it is not so good a measure of the actual fattening quality of the mixtures.

The results in Pen IV. show that 4.87 pounds of grain used was worth as much as 6.43 pounds of corn in Pen I. This grain mixture consisted of 2.44 pounds of wheat, oats and barley, equal parts, and 2.43 pounds of corn. Then if corn is worth 83 cents per hundred pounds, the wheat, oats and barley to mix with it in this fattening ration were worth $1.36 per hundred. At the present prices farmers could not afford to feed corn at all and it would be better to eliminate the oats from the ration, feeding wheat and barley as indicated in the first experiment reported in this bulletin. All these experiments show the advantage of our home grown grains in unmistakable terms.

GENERAL CONCLUSIONS.

The salient points shown in the series of pig feeding experiments reported in this bulletin are briefly:

1. Home grown grains fed in proper proportion to balance the ration are more valuable than corn.
2. A well balanced ration gives better returns in every case than a poorly balanced ration, and a mixture of grains is better than a single grain fed alone.
3. Sugar beets for swine feeding were unprofitable with us, either fed alone or in combination with grain. Green pasture would probably serve the purpose of furnishing succulent food for growing pigs at less expense.
4. Sugar beets are little more than a maintenance ration when fed alone to hogs.
5. Sugar beets and sugar beet pulp proved equally valuable in our experiments and because of its cheapness and effect on growth we believe pulp may be profitable to feed to growing pigs in connection with a grain ration, or during the first part of a fattening period.

6. These experiments indicate that sugar beets may have a value of about $1.50 per ton when fed to hogs in combination with grain.
7. Beet pulp gave a return of $1.50 per ton when fed in combination with grain.
8. Sugar beet pulp served the same purpose in our hog rations as did sugar beets and at less expense.
9. It was necessary to mix beet pulp with grain in order to educate the pigs to eat it. We would not recommend feeding more than two pounds of pulp to a pound of grain in a ration for pigs which are from 100 to 200 pounds in weight.
10. Our trials indicate that pigs take some of the nutritive property from beets, but their principal use, as well as that of pulp, seems to be mechanical.
11. Dry alfalfa hay as roughage, may be made use of by the growing pigs. In our trials the pigs ate more grain and made more gain than on a similar grain ration minus the alfalfa.
12. Comparing our results with pig feeding experiments in other states, indicates that our small grains, more especially our barley and wheat, are worth more compared with corn than similar grains raised under rainfall conditions.
13. Mixed wheat and barley ground together make a well balanced ration for pigs and one upon which they will make better growth and gain than they will on a ration composed of corn alone. The farmer in Colorado cannot ordinarily afford to sell his home grown grain and purchase corn for fattening hogs. Wheat and barley in equal parts were worth 17 percent more than corn fed alone.
14. If wheat and barley are worth $1.00 per 100 pounds, corn is worth only 83.3 cents, but many farmers sold their home grown grains for $1.00 to purchase corn at $1.30.
15. There is enough food at home, including grain, alfalfa pasture, by-products of dairies and beet sugar factories, to make swine growing and fattening a profitable industry on Colorado farms.

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LAMB FEEDING EXPERIMENTS.

1900-1902.

I. SUGAR BEETS AND BEET PULP.

II. HOME GROWN GRAINS AND CORN.

III. (*a*) SMALL GRAINS AND CORN.

(*b*) WARM AND COLD WATER.

(*c*) SHROPSHIRE GRADES AND NATIVE LAMBS.

—BY—

B. C. BUFFUM and C. J. GRIFFITH.

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PLATE I.

Fed Oats, Wheat, Barley and Alfalfa.
Given Cold Water to Drink.

PLATE II.

Fed Oats, Wheat, Barley and Alfalfa.
Given Warm Water to Drink.

LAMB FEEDING EXPERIMENTS.

BY B. C. BUFFUM AND C. J. GRIFFITH.*

The value of the by-products from the beet sugar factories is a prominent subject among lamb feeders. With the remarkable growth of the beet industry within the state there will be a corresponding increase in the tonnage of pulp available to feeders. The pulp sells at a low price per ton, so low indeed that if it has any virtue at all either for fattening or for preparing the lambs to make more profitable gains when put on full feed, it will be a valuable addition to our supply of stock food in Colorado.

To compare the value of pulp when fed with alfalfa, or with alfalfa and grain, and the value of sugar beets when fed in the same manner, we carried out an experiment at the College during the past spring. The pulp was furnished gratis for this purpose by the Great Western Sugar Company at Loveland, through the courtesy of Mr. A. V. Officer. Early in February a car load of pulp was received and hauled to the College barn where it was placed in convenient piles on the ground near the feeding pens.

Much has been written and said during the past year about the value of beet pulp, and many of the statements have been extravagant, or were without any basis of fact. It is not our intention to put any account of the feeding of pulp which has been complied from other sources in the body of this bulletin, but will state simply our own results. In our bulletin No. 73 of this Station, on the "Feeding Value of Beet Pulp and Feeding Sugar Beets and Pulp to Cows," has been published a brief resume of such data as we consider authentic, compiled from all sources to which we have had access. Our tests of sugar beet pulp for fattening hogs are reported in Bulletin No. 74 on "Swine Feeding in Colorado." This last bulletin gives the only information with which we are acquainted on feeding beet pulp to swine.

*Instructor in Animal Husbandry.

Many of our farmers have been convinced of the great worth of sugar beets in a ration for fattening stock, and in some instances they have paid more for beets for feeding than the factory would pay for manufacturing purposes. This makes the question of the value of sugar beets for feeding a live one, and we here report experiments which were carried out to throw light on this subject.

Sugar beets for fattening hogs were tried last year, and the results indicated that they were not so valuable for that purpose as many have supposed. These experiments are reported in the bulletin on "Swine Feeding in Colorado." It is well known, however, that a food suitable for one class of stock may not be suitable for another, and the results obtained with beets or pulp when fed to swine do not indicate what their nutritive quality would be when fed to lambs or cattle. Pigs require a concentrated ration, and while they may be, and in our trials were, able to live and make small gains when fed with beets alone, the ration was a bulky one and did not prove profitable. Pigs do not ordinarily live on dry hay, while lambs or cattle may lay on fat with such bulky rations, making good returns for the roughage consumed. Feeding beets or pulp to lambs along with alfalfa is very different from feeding these products to pigs when given either with or without grains or other concentrated foods.

The second experiment reported was inaugurated to compare home grown or small grains with corn, which is shipped in in great quantities by our sheep feeders, and during the past year, at least, has cost them much more than the grains which they raise on their own farms could be sold for. Many have an idea that stock of any kind cannot be fattened and properly fitted for market without using corn. Investigations in eastern states have shown that wheat is as valuable as corn for fattening stock. Our own experiments with fattening swine reported in the bulletin entitled "Swine Feeding in Colorado," show that mixtures of wheat and barley are preferable to corn for fattening pigs when either grain can be obtained at the same price as corn.

Occasionally there is introduced into the state, something new, either a new grain or a new variety which is given notoriety through the papers and which many go to considerable expense to obtain before they can know much about it. The Russian Spelt or Emmer is one of these, and in our sheep feeding trials its value has been carefully investigated. Russian Spelt, as it is popularly called (more

accurately "emmer"), is a primitive sort of wheat which does not shell out of the hull when threshed. As the kernels remain in the chaff, the grain is lighter than wheat, weighing about the same per bushel as oats, but it produces large yields and is said to be a good drouth resistant variety. In 1901, a field of this spelt on the College farm yielded sixty-three bushels per acre. The grain is very hardy. The present season we have a field of emmer growing on very poor land which is somewhat alkalized, parts of which would heretofore produce nothing but a crop of poverty weed. On this land we will get a very fair crop of grain.

The third experiment given in this bulletin was planned along the same line as the second one reported—a comparison of home grown grains with corn. Cold water was also compared with warm water in this same trial. A third comparison made in this experiment was the relative gain made by Shropshire crosses and native western lambs. These so-called Shropshire crosses were the first cross of pure bred Shropshire bucks on the native merino grade ewes. They were raised at the College farm from some old native ewes which had been purchased for an experiment.

Seven years ago the Station published Bulletin No. 32 on "Sheep Feeding in Colorado," prepared by Professor W. W. Cooke. That bulletin contains some information of general value and some interesting feeding experiments are reported. Those who are making a study of the lamb feeding problem will be interested enough to compare the results reported at that time and those given in the present bulletin, more especially, perhaps, the results from feeding sugar beets. The cost for each pound of gain where beets formed a portion of the ration was higher than the cost per pound of gain with grain rations, and the profit was not sufficiently large to make beet feeding remunerative. Professor Cooke reported a maximum return from feeding beets of $2.77 per ton and gives a low value of grain when added to a beet ration. The investigations reported in the present bulletin tend to substantiate that view. Because of the low cost of beet pulp, however, it forms a cheap substitute for the more expensive roots and the pulp seems to serve the purpose of adding a succulent food so well that there is considerable advantage to be gained from its proper use.

The comparative value of wheat and corn for lamb feeding where the lambs are finished on either of these grains, as reported in Bulletin No. 32, shows wheat to be

worth 15 percent more than corn, but under other conditions and for the entire trials then made, the wheat and corn were almost exactly equal to each other. The results with corn in our more recent trials show that the high prices paid by our farmers for corn during the past year were more than it was actually worth when compared with our home grown grains at their prevailing market prices. The high prices received for fattened lambs made the feeding of corn at $1.30 per hundred pounds profitable, but the man who properly fed wheat and barley at one cent per pound would have an appreciably larger balance on the right side of his ledger. It is the province of the Experiment Station to investigate these subjects and furnish the information to all who desire it. In addition to Bulletin No. 32 on sheep feeding, the Station has published Bulletin No. 52 on "Pasturing Sheep on Alfalfa and Raising Early Lambs."

EXPERIMENT I.--SUGAR BEETS AND BEET PULP.

KIND OF LAMBS FED.

In the first and second experiments here reported, we used Mexican lambs which averaged 55 pounds per head March 5th, 1902. They were in very poor condition when we received them, a few days prior to the beginning of the experiment. They had trailed a long distance to Albuquerque, New Mexico, at which place they were held until they could be dipped twice. During the interval between the dippings they were kept on the sand hills where there was practically no food to be had. This class of lambs would represent the most unprofitable kind that could be had for feeding anywhere in the west. The resulting profit obtained, then, may be considered a minimum In April the lambs were shorn and the wool credited at ten cents per pound.

OBJECT AND PLAN OF EXPERIMENT I.

The object of this trial was to determine the comparative value of sugar beets and beet pulp when fed with alfalfa hay either alone or in combination with grain. Fifty lambs had been divided into ten lots of five each and five of these lots were to receive beet and pulp rations. Lots I. to IV. are regularly reported. Lot X. was given a ration of beets, grain and straw, in order to show the comparative return from feeding alfalfa and to determine whether the beets and straw could be made to take the place of alfalfa. Some of our farmers have thought that sugar beets had such a high feeding value that they could be made to take the place largely of both hay and grain. We failed to get the lambs in Lot X. fat enough to turn and considered the trial so much out of the ordinary that it would not be worth while to compare the results more than in a general way. So this lot does not appear in our tables. The following rations were fed to those in the sugar beet and pulp trial:

Lot I.—Alfalfa and beet pulp.

Lot II.—Alfalfa and beet pulp with grain consisting of equal parts of barley and wheat added during the last eight

weeks the lambs were fed; cutting off all the pulp during the last thirty days.

Lot III.—Alfalfa and sugar beets.

Lot IV.—Alfalfa and sugar beets with grain consisting of equal parts of wheat and barley added during the last eight weeks the lambs were on feed, cutting off the supply of sugar beets during the last thirty days.

The alfalfa was fed *ad libitum*, a complete record being kept of amount of fed and amount not eaten. It was the intention to feed all the pulp and beets that the lambs would eat, but it was not kept before them all the time.

Each lamb was marked, and weighed separately once a week in order to keep complete individual records of them as well as accounts of the lots. The lambs were selected carefully in order that there should be no advantage of any one lot over another by having in it a superior class of individuals.

In Experiments I. and II., the feeding was done and the notes taken by senior students under the direction and supervision of one of us. Our acknowledgments are due more especially to Mr. E. P. Taylor and Mr. H. J. Faulkner.

In computing comparative values and the cost of food eaten, cost for each pound of gain, etc., local market prices of the food used are as follows:

Alfalfa on the farm, $4.00 per ton.

Beet pulp delivered, $1.00 per ton.

Sugar beets on the farm, $4.00 per ton.

Wheat and barley, $1.00 per hundred pounds.

RESULTS OF EXPERIMENT I.

Nothing occurred to mar or interfere with this experiment except the necessity of feeding a small amount of grain during the first week to induce the lambs to begin eating the pulp and beets at once and a mistake which was made during the last three weeks when Lot III. receiving the beets were given grain. As all the lots received the same amount of grain the first week, the value of the comparisons of one lot with another are not disturbed. By drawing the conclusions for the first five weeks and for the first ten weeks, we are able to eliminate the effect of the grain given during the last thirty days to the pulp and beet lots, and show the comparative value of beets and pulp.

The beets showed a tendency to scour the lambs when they ate too large a quantity of them. The lambs in Lot IV. and one lamb, No. 7, in Lot II., were out of condition

once during the feeding period by having been fed too liberally.

Table I. gives the amounts of food supplied to each lot during each week, with the total amount fed each lot and the orts not eaten which were weighed back each day.

TABLE I.

LAMB FEEDING. SUGAR BEETS AND BEET PULP.
FOOD EATEN IN POUNDS.

	Lot I.					Lot II.					Lot III.					Lot IV.				
	Pulp	Pulp Orts	Alfalfa	Alfalfa Orts	Barley and Wheat	Pulp	Pulp Orts	Alfalfa	Alfalfa Orts	Barley and Wheat	Sugar Beets	Sugar Beet Orts	Alfalfa	Alfalfa Orts	Barley and Wheat	Sugar Beets	Sugar Beet Orts	Alfalfa	Alfalfa Orts	Barley and Wheat
Mar. 5 to Mar. 12	107	40	96	32	8.0	103	53	96	42	8	81	15	96	38	8	75	31	96	32	8
Mar. 12 to Mar. 15.	42	2	36	12	..	42	14	36	9	..	42	2	36	14	...	42	3	36	19	...
Mar. 15 to Mar. 22	102	4	84	29	..	102	7	84	22	...	98	3	84	33	...	98	5	84	45	...
Mar. 22 to Mar. 29.	124	5	84	19	..	124	1	84	20	...	94	4	84	27	...	104	...	84	23	...
Mar. 29 to April 5 .	132	9	84	22	....	132	5	84	15	...	108	1	84	21	...	108	...	84	26	...
April 5 to April 12.	142	10	84	20	....	97	...	84	15	18	112	2	84	24	...	79	...	84	19	17
April 12 to April 19	147	6	84	24	.	91	.	84	32	22	128	.	84	37	.	97	...	84	25	23
April 19 to April 26	147	5	112	39	.	91	1	84	15	33	116	...	84	18	...	97	.	84	18	33
April 26 to May 3..	193	4	112	35	..	90	37	94	40	47	151	3	94	27	...	84	6	91	40	51
May 3 to May 10...	280	10	112	11	....	...	...	98	20	51	160	...	98	12	...	...	...	98	11	60
May 10 to May 17..	272	21	112	32	5.5	...	...	98	22	49	39	...	102	23	31	...	...	98	21	73
May 17 to May 24..	217	38	113	30	6.0	...	...	98	41	45	18	...	112	41	63	...	...	98	28	81
May 24 to May 28..	90	22	45	7	....	...	...	40	8	29	....	...	45	6	26	...	...	40	8	30
Totals............	1974	199	1155	314	19.5	878	113	1164	279	302	1166	30	1087	321	128	784	45	1061	315	376

Table II. gives the average amount of food actually consumed by each lamb daily. The alfalfa left uneaten

consisted of the coarser stems and these were consumed readily by the stock sheep. It was necessary at first to sprinkle the pulp with grain in order to get the lambs to eat it at all. Near the end of the trial the supply of sugar beets gave out and a little grain was added to the ration given Lot III.

TABLE II.

AVERAGE FOOD EATEN DAILY IN POUNDS.

	Alfalfa.	Pulp.	Sugar Beets.	Wheat and Barley.	Total Food Daily.
Lot I.	2.02	4.22		0.04	6.28
Lot II.	2.10	1.82		0.72	4.64
Lot III.	1.82		2.70	0.30	4.82
Lot IV.	1.77		1.76	0.90	4.43

The amount of alfalfa, pulp and grain consumed by the five lambs in Lot I. was 6.28 pounds per head daily; 2.02 pounds of alfalfa, 4.22 pounds of pulp and .04 pounds of grain; or a total of 168.2 pounds of alfalfa, 375 pounds of pulp and 3.9 pounds of grain per head during the 84 days feeding.

Lot III. ate a ration of 1.82 pounds of alfalfa, 2.70 pounds of sugar beets and .30 pounds of grain per head daily, making a total ration of 4.82 pounds consumed daily; or a total amount of food eaten per lamb through the experiment of 153.2 pounds of alfalfa, 227.2 pounds of sugar beets and 25.6 pounds of grain.

There were 2.10 pounds of alfalfa, 1.82 pounds of pulp and .72 pounds of grain consumed daily by the average lamb in Lot II., a total daily food of 4.64 pounds, or a total through the period of 177 pounds of alfalfa, 153 pounds of pulp, and 6.04 pounds of grain.

Lot IV. consumed an average daily ration of 1.77 pounds of alfalfa, 1.76 pounds of sugar beets and .90 pounds of wheat and barley, a total daily ration of 4.43 pounds per lamb. This makes a total of 149.2 pounds of alfalfa, 147.2 pounds of sugar beets, and 75.2 pounds of grain consumed through the experiment by the average lamb in this lot.

The total amounts of food consumed for the entire period are as we should expect to find them, greater in those lots having pulp than in those having the beets, probably because of the greater percent of nutrients in the beets.

WEIGHT AND GAINS PER WEEK ON PULP AND BEET RATIONS.

Table III. gives by weeks the individual weights of the lambs in the four lots during the trial, and the total gain

made by each. Lamb No. 4 in Lot I. did poorly, making a gain of only eight pounds for the whole time, while the other four lambs in the pen made an average of 17 pounds each. For the first five weeks while on pulp and alfalfa the other four lambs in Lot I. made average gains of 9.7 pounds, while lamb No. 4 gained only three pounds. This lamb making a gain so much smaller than the normal will explain in part at least the difference in gains of Lot I. and

TABLE III.

INDIVIDUAL WEIGHTS AND GAINS IN POUNDS.

	Lot I.					Lot II.					Lot III.					Lot IV.				
Tag No	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
March 5	61	53	57	53	60	59	64	58	54	54	60	39	52	56	52	69	57	60	54	49
March 12	68	54	60	58	64	64	69	61	60	63	60	47	56	58	57	73	63	64	60	55
March 15	66	57	61	56	65	63	67	60	60	61	61	45	58	58	57	77	68	67	60	59
March 22	68	57	63	55	67	64	69	63	62	64	64	51	59	61	59	75	66	64	63	52
March 29	67	59	63	53	71	67	64	63	65	68	65	52	61	63	62	77	70	61	64	55
April 5	71	62	64	56	73	69	69	64	65	73	68	56	65	65	64	79	72	65	66	56
April 12	69	62	65	57	74	71	70	62	67	75	66	56	65	67	66	80	76	67	68	59
Sheared April 19	67	61	64	56	74	70	68	64	66	75	67	58	65	64	61	78	77	69	68	55
April 26	70	63	66	55	82	75	71	64	70	79	69	59	68	66	65	83	75	72	73	61
May 3	74	69	69	53	85	77	73	69	68	78	71	63	73	68	69	86	83	75	75	60
May 10	75	69	70	62	83	78	73	71	72	77	72	63	70	69	71	84	87	78	78	65
May 17	74	71	71	60	84	74	74	71	74	81	77	61	72	69	74	87	89	78	81	68
May 24	77	72	73	62	86	80	78	73	73	83	78	63	75	71	77	90	90	82	80	71
May 28	74	71	72	61	82	80	77	72	73	81	78	68	74	69	76	90	87	82	79	72
Fleece	4	3	3	4	2	4	4	2	4	3	4	2	3	4	3	6	2	2	3	4
Total Gain	17	21	18	12	24	25	17	16	23	30	22	31	25	17	27	27	32	24	28	27

Lot II. during the first five weeks when both lots were receiving the same ration of pulp and hay.

TABLE IV.

POUNDS GAIN PER WEEK—WITHOUT GRAIN.

	Lot I.*	Lot II.*	Lot III.†	Lot IV.†
March 8	20	28	19	26
March 15	1	6	1	16
March 22	5	11	15	–11
March 29	3	6	9	7
April 5	13	12	15	11
Gain	42	51	59	49

*Lots I. and II. fed pulp and alfalfa.
†Lots III. and IV. fed beets and alfalfa.

TABLE V.

POUNDS GAIN PER WEEK—WITH GRAIN.

	Lot I.*	Lot II.†	Lot III.‡	Lot IV.§
April 12	1	5	2	12
April 19	11	15	11	14
April 26	14	16	12	17
May 3	14	6	17	15
May 10	9	6	1	13
May 17	1	3	8	11
May 24	10	13	11	10
May 28	–10	–4	1	–3
Gain	50	60	63	89
Total Gain Flesh (March 8–May 28)	76	94	106	121
Fleece	16	17	16	17
Total Gain with Fleece Mar. 8–May 28)	92	111	122	138

*Lot I. fed pulp and alfalfa.
†Lot II. fed pulp, alfalfa and grain.
‡Lot III. fed beets, alfalfa (grain three weeks.)
§Lot IV. fed beets, alfalfa and grain.

Table IV. shows that the ten lambs of Lots I. and II. fed pulp and alfalfa for five weeks gained 93 pounds. In order to get the lambs to eat the pulp 16 pounds of grain was mixed with it for the two lots during the first week, and during this time while receiving the grain they made a total gain of 38 pounds, leaving 55 pounds gain due to the pulp and alfalfa fed the other four weeks.

Lots III. and IV. consisted of 10 lambs fed on sugar beets and alfalfa, and they gained 108 pounds during the first five weeks. They were fed the same amount of grain during the first week as Lots I. and II. The gains made by the 10 lambs fed with beets during the first week amounted to 45 pounds, leaving 63 pounds of gain due to sugar beets and alfalfa in the remaining four weeks, or eight pounds more gain for the beets than for the pulp.

Table V. shows that the five lambs in Lot I. made a total gain of 92 pounds, 16 pounds of which was fleece, while those fed beets and alfalfa made a total gain of 122 pounds, 16 pounds of which was fleece. However, the beet fed lambs received 99 pounds of grain more than those which were fed pulp. The pulp fed lambs in Lot I. were given 11½ pounds of grain in the two weeks from May 10 to May 24, and Lot III. which was fed beets received 120 pounds of grain during the last three weeks of the experiment.

In our plan of the experiment it was not the intention that the pulp and beet fed lambs should have any grain at all.

Referring to Table V. it will be seen that the pulp fed lambs made but one pound gain during the last three weeks, while the beet fed lambs made an appreciable gain during this time when the grain was given them. The gain made by Lot III. during the last three weeks was 20 pounds, but during this time they received only 57 pounds of beets, and the principal part of the gain was due, no doubt, to the grain fed.

Lot III., fed beets and alfalfa, gained 122 pounds during the experiment, 16 pounds of which was fleece. Deducting the 20 pounds gain while being fed grain, and the amount of fleece, and comparing with Lot II., the results would indicate that the beet and alfalfa lot gained 10 pounds more than the lot which received pulp and alfalfa. This statement must be taken with due allowance because the five lambs ate almost two and one-half pounds of beets per day during the last three weeks and they may have produced an appreciable effect on the gains.

Lot II., which was fed pulp, alfalfa and grain, gained 111 pounds, 17 pounds of which was fleece, and Lot IV. fed beets, alfalfa and grain, gained 138 pounds, 17 pounds of which was fleece. Then the lots fed beets and grain gained 27 pounds more than the lot fed pulp and grain, the fleece being the same in each case.

Adding grain to the pulp and alfalfa ration gives an increased gain of 10 pounds over the pulp and alfalfa ration during the last eight weeks of the experiment. No comparison can be made between the beet, alfalfa and grain ration and the beet and alfalfa ration for the whole time, because of the amount of grain given to Lot III. during the last three weeks. However, by taking the first 10 weeks of the feeding period, leaving out the last three weeks, we are able to make a fair comparison between the lots.

Briefly stated up to this time, (May 10), Lot I., on pulp, gained in flesh 75 pounds, Lot III., on beets, gained 86 pounds, or eleven pounds more for the beet ration than for the pulp ration. Lot II., fed pulp and grain, gained 82 pounds, or seven pounds more than those on pulp without grain, and four pounds less than Lot III. on beets and alfalfa. Lot IV., on beets and grain, gained 103 pounds for this ten weeks' period, or 28 pounds more than Lot I. on pulp; 27 pounds more than those on beets and alfalfa, and 21 pounds more than those on pulp and grain.

For the ten weeks' period Lot I. ate 1277 pounds of pulp and 640 pounds of hay worth $1.82. Lot III. ate 1079 pounds of beets and 577 pounds of hay worth $3.31. The beet lot gained 11 pounds more than the pulp lot, worth 66 cents. Then $1.82 worth of pulp and hay was equal to $2.65 worth of beets and hay when fed without grain. The hay being the same, the pulp would be worth $1.46 per ton compared with beets at $4.00 per ton when fed with hay alone. There was actually more hay eaten with the pulp than with the beets so the difference would not be quite so great. Making the same comparison between the lots which were fed grain with pulp and with beets, Lot II. ate in the ten weeks 765 pounds of pulp, 720 pounds of hay and 179 pounds of grain, while Lot IV. ate 784 pounds of beets, 566 pounds of alfalfa and 192 pounds of grain. The food eaten by Lot II. was worth $3.62 and that eaten by Lot IV. was worth $4.62. Lot IV. gained 21 pounds more than Lot II. which was worth $1.25. Then $3.62 worth of pulp, alfalfa and grain was equal to $3.36 worth of beets, alfalfa and grain. The beets would be worth a little more than

TABLE VI.

FOOD EATEN AND GAINS IN POUNDS.

	No. lambs	No. dys fed	Food Eaten					Average Weight		Total gain flesh	Fleece
			Alfalfa	Sugar Beets	Pulp	Wheat	Barley	At be-gin'ing	At end		
Lot I......	5	84	841	....	1775	9.75	9.75	56.8	72.2	76.0	16.0
Lot II.	5	84	885	....	765	151.00	151.00	57.8	76.6	94.0	17.0
Lot III	5	84	766	1136	....	64.00	64.00	51.8	73.0	106.0	16.0
Lot IV ...	5	84	746	739	.... ..	188.00	188 00	57.8	82.0	121.0	17.0

$4.00 per ton compared with pulp at $1.00 per ton when fed in this way with grain at one cent per pound.

The whole discussion indicates that so far as the results of this experiment are reliable, pulp at $1.00 per ton, with alfalfa at $4.00 per ton, is a much more economical ration than beets at $4.00 per ton, with hay at the same price, when no grain is given, but that a ration of pulp, alfalfa and grain is approximately equal to beets, alfalfa and grain at $1.00 and $4.00 per ton respectively.

Table VI. gives the total amount of food eaten by each lot and the gains made.

AMOUNT AND COST OF FOOD COMPARED WITH GAINS.

Table VII. gives the amount and cost of food consumed for one pound of gain made in each lot, also the average percent of dressed weight for the respective lots.

TABLE VII.

FOOD EATEN FOR ONE POUND GAIN.

	Food for One Pound Gain					Cost 1 lb. Gain	Percent Dressed Weight
	Alfalfa	Sugar Beets	Pulp	Wheat	Barley		
	lbs.	lbs.	lbs.	lbs.	lbs.	cts.	
Lot I.......	9.14	....	19.30	0.02	0.02	2.83	45.7
Lot II.. ..	7.97	....	6.90	1.36	1.36	4.65	48.1
Lot III ...	6.28	9.31	....	0 52	0.52	4.16	46.6
Lot IV . .	5.40	5.35	....	1.36	1.36	4.87	46.6

Comparing Lots I. and II. we find that 9.14 pounds of alfalfa; 19.3 pounds of pulp, and .04 pounds of grain in Lot I. was equal to 7.97 pounds of alfalfa; 6.9 pounds of pulp and 2.72 pounds of grain in Lot II. In Lot III. where sugar beets took the place of the pulp in the ration of Lot I. it required 6.28 pounds of alfalfa, 9.31 pounds of beets and 1.04 pounds of grain to produce one pound of gain; or it took 9.31 pounds of beets and 1.00 pound of grain in Lot III. to replace 19.3 pounds of pulp and 2.86 pounds of alfalfa in Lot I.

Lot IV., which had a similar ration to Lot II., except that the pulp in Lot II. was replaced with with beets in Lot IV., required 5.4 pounds of alfalfa, 5.35 pounds of beets and 2.72 pounds of grain for one pound of gain. The extra

grain in Lot IV. of 1.68 pounds for each pound of gain replaced .88 pounds of alfalfa and 3.96 pounds of sugar beets in the ration of Lot III.

Because of the cheapness of the food the pulp and alfalfa made the gain cheaper than the other rations. The cost of each pound of gain was 2 83 cents in Lot I. fed pulp, 4.16 cents in Lot III. fed beets, 4.65 cents in Lot II. fed pulp and grain and 4.87 cents in Lot IV. fed beets and grain. As would be expected, the percent of dressed weight was smallest with the pulp fed lambs. They dressed out 45.7 percent of the live weight against 46.6 percent for the sugar beet lot, 48.1 percent for the pulp and grain lot and 46.6 percent for the beet and grain lot. The amount of alfalfa consumed for each pound of gain was greatest in the pulp fed lot and least with the lot fed beets and grain.

When the lambs were slaughtered pieces of the meat were sent to a number of people with the request that they furnish an opinion in regard to the quality of the mutton. With one exception all those who received the samples of mutton stated that the first piece, which was pulp and alfalfa fed, possessed good flavor and quality, but was not so fat as the second piece which was corn fed. The following letter from Mrs. Carpenter is typical of the general opinion. Those receiving the samples did not know what kind of food had been given the lambs:

"We received the two samples of mutton and I cooked them both by boiling. The flavor of the first piece was so delicate that it was hard to realize that it was mutton. Yet we liked the second piece better as it was fatter and juicier, and we prefer fat, juicy mutton. The flavor of the second piece was more like the mutton we are are accustomed to."

NOTE. Lot X. was fed straw, beets, wheat and barley and made a total gain of 74 pounds. They consumed 436 pounds of wheat and barley, worth \$4.36, 683 pounds of sugar beets, worth \$1.37, 512 pounds of straw which we will estimate at \$1.00 per ton or 25.6 cents. The total cost for the food is \$5.99. The value of the gain is 62 pounds of flesh at 6 cents, equals \$3.72, and 12 pounds of fleece at 10 cents, \$1.20, or \$4.92. This gives a loss of \$1.07, providing the lambs had been fit for market. As they were not fat enough to slaughter this does not express the total loss. The alfalfa, beet and grain ration in Lot IV. above gave a profit on the gain of \$2.23. This forcibly illustrates the value of alfalfa and the fact that sugar beets must be supplemented with other nutritious roughage in order to give profitable returns.

PLATE III.

Fed Corn and Alfalfa.
Given Warm Water to Drink.

PLATE IV.

Fed Corn and Alfalfa.
Given Cold Water to Drink.

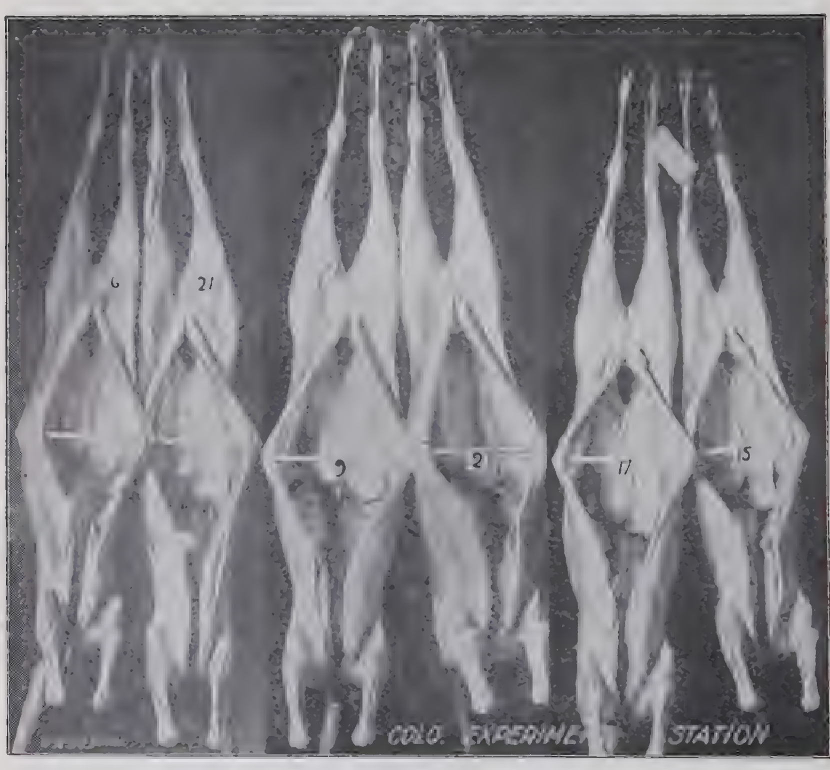

PLATE V.

Representative Carcasses of Lots I, II, III, IV and V.

COST AND PROFIT.

Table VIII. gives the cost and profit from feeding lambs with sugar beets and beet pulp rations. The estimate of profit is based on a price of six cents per pound for the gain made during the feeding period and is the comparative rather than the total profit. The total profit would vary with the first cost of the lambs and the selling price. Our lambs cost us almost five cents per pound, and if sold at an advance of one cent, or six cents per pound when fat, the profit would be increased by the cent per pound for the weight of the lambs when put on feed, or an average of about 55 cents, amounting to $2.75 more for the fat lambs in each pen than the profit indicated in the last column of the table.

TABLE VIII.

COST AND PROFIT.

	Feed.	Cost of Feed.	Cost 1 lb. Gain.	Value Gain @ 6 cts.	Value Wool @ 10 cts.	Total Value of Gain.	Profit.
		$	cts.	$	$	$	$
Lot I......	Pulp, Alfalfa,	2.76	2.83	4.56	1.60	6.16	3.40
Lot II.....	Pulp, Grain, Alfalfa	5.17	4.65	5.64	1.70	7.34	2.17
Lot III....	Beets, Alfalfa,*	5.08	4.16	6.36	1.60	7.96	2.88
Lot IV.....	Beets, Grain, Alfalfa	6.73	4.87	7.26	1.70	8.96	2.23

*Fed grain last three weeks.

The cost for each pound of gain was the lowest for Lot I. fed pulp and alfalfa. A good gain was made by this lot and the low cost of the food made the cost per pound of gain only 2.83 cents, while the total profit on the gain is $3.40 which is the highest return made by any lot in either experiment I. or experiment II. (See Table XV. Experiment II). While the profit was greater than that from any other lot their total gain and the per cent of dressed weight was lower than any of the others which might have produced an appreciable effect on their selling price in the open market. All the figures here given account for one day's shrinkage in the yards, but if shipped a long distance it is not unlikely that the shrinkage would be greater from the pulp fed lambs.

The next best profit was from Lot III. given sugar beets and alfalfa with some grain the last thirty days. This lot

ate less food and made larger gains than the pulp fed lambs, but the increased cost of food reduced the profit. Lot IV. fed beets and grain made a greater profit than Lot II fed pulp and grain, though the difference is small. The total value of the food steadily increases as the grain and beets are added to the ration, and the total gains made also increase but not in proportion to the increased cost of food.

The object of lamb feeding in Colorado is to find a market for the surplus alfalfa and the profit from such feeding is often expressed by the value received for the hay so used. Then giving the other foods their local market values the hay made returns in this experiment of $[illegible] per ton in Lot I.; $7.36 per ton in Lot II.; $9.86 per ton in Lot III. and $8.18 per ton in Lot IV. Giving the alfalfa a local value of $4.00 per ton on the farm, the profit for the gains made would show a return from feeding pulp with it in Lot I. of $4.28 per ton and $4.88 per ton on Lot II. Allowing $4.00 per ton for alfalfa and one cent per pound for the grain, the sugar beets made a return in Lot III. of $[illegible] per ton and in Lot IV. the return from the beets would be $8.22 per ton. When one begins to compute returns made by any one food in this way he realizes at once that at best the results are only comparative. There is nothing to show that the food which appears to have given the return indicated actually did produce its proportion of the gain. Again the final value will vary greatly with the proportion of each food consumed in the ration. However, as a means of comparison it serves a purpose. The figures we have given show that pulp gave approximately one-half the return pound for pound that was obtained from beets, but because of its cheapness it gave an apparently large value for the hay fed with it in Lot I. All of our estimates of cost and profit are based on amount of food eaten and the value of the gain. This method is sufficient for reliable comparisons and is used with the assumption that the increased selling price over the price paid for feeders will meet all labor expense and necessary waste.

LAMB FEEDING EXPERIMENT NO. 2.

Experiment No. 2 was planned and carried out concurrent with and as a part of Experiment No. 1. The lambs used in these trials were from the same flock. The separate lots in the two experiments were all selected at the same time in order to avoid as much as possible any error in individuality due to improper care in selecting. The object of this experiment was to compare our home grown grains and combinations of them with corn. These two experiments—first and second—having the same conditions throughout, and there being no apparent difference in the class of animals used, afford an excellent opportunity to show the comparative profits of pulp, sugar beets, corn and our home grown grains when fed with alfalfa for fattening lambs.

As stated before, these were Mexican lambs and were in very poor condition for that class. The returns then should represent the minimum profits at the price per pound allowed for the grain. In order to eliminate any confusing data the profits are figured on gain only and no attempt was made to show actual profits by taking into consideration the initial cost to us and the final income when the lambs were sold. The lambs in both these experiments were treated alike in everything except the kinds of food given. They were fed and watered at regular hours twice each day, and the waste not eaten was weighed back daily. The lambs were sheared during the week, April [illegible] to April 19th and the wool credited to them at the selling price, which was ten cents per pound. Careful notes were kept to put on record complete information of the progress of the experiment. No unusual incidents or accidents occurred which would seriously mar the experiment. Lamb No. 37 in Lot VIII. became entangled in the fence and was found dead the morning of the day the other lambs were slaughtered. His live weight at the end of the previous week having been secured, and the fact that the gain for the last week so nearly offset the shrinkage during the last twenty-four hours when they were off feed, makes no correction necessary in reporting the results. The per cent of dressed weight for Lot VIII. is averaged for four instead of for five lambs.

April 10th lamb No. 43 in Lot IX. dropped a buck lamb which was taken away and she was allowed to remain on

feed until the end of the experiment. She did so poorly, however, that in order to compare this lot with the others in profits, the averages for Lot IX. are taken from the remaining four lambs as indicated by foot notes in the tables when the correction is necessary.

TABLE IX.

FOOD EATEN, IN POUNDS.

	Lot V.			Lot VI.			Lot VII.			Lot VIII.			Lot IX.		
	Corn	Alfalfa	Alfalfa Orts	Spelt or Emmer	Alfalfa	Alfalfa Orts	Barley	Alfalfa	Alfalfa Orts	Wheat and Barley	Alfalfa	Alfalfa Orts	Wheat and Emmer	Alfalfa	Alfalfa Orts
March 5—March 8	6.9	52	24	6.9	52	22	6 9	52	10	6.9	52	10	6.9	52	13
March 8—March 15	17.5	105	46	17.5	105	45	17.5	105	38	17.5	105	48	17.5	105	43
March 15—March 22	19.4	97	41	19.4	97	42	19.4	97	42	19.4	97	44	19.4	97	41
March 22—March 29	21.9	114	54	21.9	114	51	21.9	114	45	21.9	114	53	21.9	114	50
March 29—April 5	23.1	120	53	23.1	120	51	23.1	120	51	23.1	120	54	23.1	120	52
April 5—April 12	26.2	122	58	26.2	122	53	26.2	122	52	26.2	122	61	26.2	122	57
April 12—April 19	26.2	122	55	26.2	122	49	26.2	122	49	26.2	131	53	26.2	122	60
April 19—April 26	32.5	132	55	32.5	132	46	32.5	132	47	32.5	132	57	32.5	132	54
April 26—May 3	36.2	136	67	36.2	135	56	36.2	135	55	36.2	135	81	36.2	135	67
May 3—May 10	40.0	117	44	40.0	117	35	40.0	117	39	40.0	117	64	40.0	117	55
May 10—May 17	48.8	130	76	48.8	130	62	48.8	130	67	41.1	130	54	48.8	130	74
May 17—May 24	43.7	106	55	43.8	106	40	43.7	106	46	43.7	106	59	43.7	106	53
May 24—May 31	43.7	105	47	43.7	105	36	43.7	105	46	43.7	105	58	43.7	105	56
May 31—June 6	15 9	37	18	43.7	37	17	15.9	37	19	63.6	136	54	49.8	106	55
Totals	402.0	1495	693	430.0	1494	605	402.0	1494	606	442.0	1602	750	436.0	1563	730

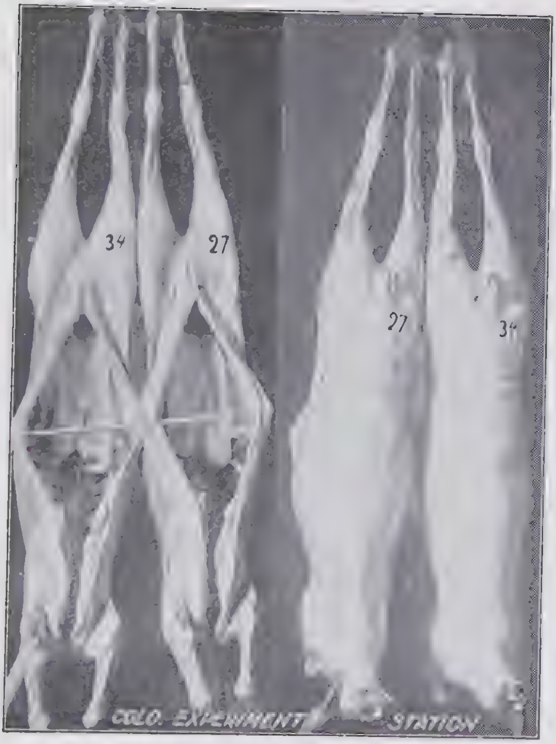

PLATE VI.

Representative Carcasses of Lots VI and VII.

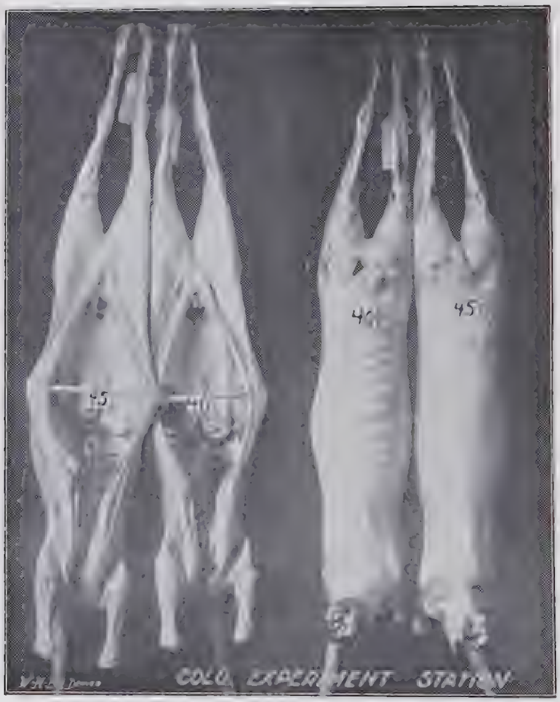

PLATE VII.

Representative Carcasses of Lots VIII and IX.

PLAN OF EXPERIMENT NO. 2.

The plan of the experiment was as follows:

Lot V. was fed corn and alfalfa.

Lot VI. was fed spelt (emmer) and alfalfa.

Lot VII. was fed barley and alfalfa.

Lot VIII. was fed wheat, barley and alfalfa, the wheat and barley in equal amounts.

Lot IX. was fed wheat, spelt (emmer) and alfalfa, the wheat and spelt in equal amounts.

Lots V., VI. and VII. were fed ninety days. Lots VIII. and IX. ninety-five days.

The alfalfa was fed in such quantities that it would be before the lambs all the time. The corn and other grains were fed in small quantities at first, increasing the amount gradually to one and one-quarter and one and one-half pounds daily per lamb. The larger amount was fed only a short time. The feed was charged at local prices, which were at the time of the experiment $4.00 per ton for alfalfa on the farm, $1.30 per hundred pounds for corn, and one cent per pound for the wheat, barley and spelt.

Table IX. shows the amount of food given each lot for periods of one week, also the total amounts given each lot and the amount of waste. This table shows the details of the feeding, the increase in the gain, and any irregularity which may have occurred in the appetites of the animals.

Table X. shows the average amount of each kind of food and the total daily consumption by each lamb. Lot VI. fed alfalfa and spelt, ate more food than any of the others, although the total daily consumption of food differs little in any of the lots. The lambs in Lot IX. ate less alfalfa than those in any of the other lots, and less total food daily. They were given wheat and spelt, which could

TABLE X.

AVERAGE FOOD EATEN DAILY, IN POUNDS.

	Alfalfa.	Corn.	Wheat.	Barley.	Spelt.	Total Food.
Lot V	1.78	0.88	....	....	....	2.66
Lot VI	1.97	....	....	....	0.95	2.92
Lot VII	1.96	....	....	0.88	....	2.84
Lot VIII	1.80	....	0.465	0.465	....	2.73
Lot IX	1.75	....	0.459	....	0.459	2.67

hardly be considered a variety of food because the spelt is a wheat, differing from the common variety principally in the chaff which encloses the spelt kernels. The lambs got off feed more quickly on this ration than on any other and made comparatively poor gains.

TABLE XI.

INDIVIDUAL WEIGHTS AND GAINS, IN POUNDS.

	Lot V.					Lot VI.					Lot VII.					Lot VIII.					Lot IX.				
Tag No	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
March 5	55	58	53	54	49	56	50	55	54	54	59	58	58	58	54	51	43	48	44	50	61	54	55	52	62
March 8	59	68	57	57	53	57	59	62	60	64	62	63	63	63	63	50	51	50	49	52	65	58	60	55	67
March 15	65	72	65	60	56	65	60	65	63	62	69	64	62	64	62	57	54	59	56	60	67	60	65	54	69
March 22	64	71	63	60	57	61	61	65	63	60	66	62	63	61	63	54	54	57	55	59	66	57	64	53	61
March 29	67	76	65	60	61	66	63	68	66	63	68	67	68	67	68	54	59	61	59	63	69	60	69	56	69
April 5	69	80	69	65	64	62	66	71	68	66	72	68	70	68	68	63	61	62	60	65	71	64	72	58	72
April 12	68	80	65	63	64	71	65	69	66	66	68	67	69	70	66	61	60	62	60	66	72	63	66	58	72
April 19	63	76	62	64	59	67	65	67	64	62	64	67	69	67	62	66	62	61	59	64	71	58	55	56	68
April 26	66	81	65	68	62	70	65	70	68	64	68	68	70	69	68	64	64	63	60	66	73	61	57	58	70
May 3	72	88	63	76	67	76	75	74	73	68	76	75	74	75	74	68	63	62	62	70	76	60	61	63	75
May 10	70	82	68	73	66	78	75	80	74	69	74	75	77	74	74	70	69	69	65	75	79	68	63	64	78
May 17	68	84	68	75	68	78	72	79	72	70	72	70	76	71	72	64	65	60	59	69	65	65	56	59	72
May 24	73	88	69	75	69	78	75	81	74	71	73	74	76	72	77	70	68	61	62	75	79	66	58	64	77
May 31	75	91	74	78	74	82	80	84	77	75	75	75	79	76	79	76	71	69	65	75	82	67	59	64	76
June 3	76	81	73	79	73	82	77	84	78	75	76	76	79	75	78	75	died	66	65	76	82	69	60	71	77
Fleece	2	3	5	3	4	3	3	4	2	3	3	3	5	3	6	3	1	3	4	3	2	4	3	2	3
Total Gain	23	26	25	28	28	29	30	33	26	24	20	21	26	20	30	27	29	21	25	29	23	19	8	21	18

WEIGHTS AND GAINS PER WEEK—CORN AND SMALL GRAINS.

Table XI. reports the individual weights and gains made by each lamb. The weights for April 19th were made after shearing, and the apparent loss that week is due to the removal of the fleece.

Lamb No. 43 in Lot IX. is one previously spoken of which it is necessary to drop out in making the final averages. All the others make fair gains.

Table XII. gives the gain or loss each week for the five lambs in each lot.

TABLE XII.

POUNDS GAIN PER WEEK.

	Lot V.	Lot VI.	Lot VII.	Lot VIII.	Lot IX.
March 8	25	33	27	16	21
March 15	24	13	7	34	10
March 22	–3	–5	–6	–7	14
March 29	14	16	23	17	22
April 5	18	7	8	15	14
April 12	–7	4	–6	–2	–6
April 19	1	3	9	17	–9
April 26	18	12	14	5	11
May 3	24	29	31	8	16
May 10	–7	10	0	23	17
May 17	4	–5	–13	–31	–35
May 24	11	8	11	19	27
May 31	18	19	12	20	4
June 9	–10	–2	0	–3	11
Total Gain Flesh	113	127	97	117	75
Fleece	17	15	20	14	14
Total Gain with Fleece	130	142	117	131	89

The losses on April 19th were due to taking away the fleece that week. There is much variation in the gains week by week. The table shows that all the lambs except those in Lot V. lost weight during the week of May 10th to 17th. This was evidently due to the over feeding of grain. On May 9th the ration of grain was increased in all the lots, from one to one and one-quarter pounds per head daily to one and one-half pounds per head. Our notes show that during this week the lambs refused to eat up all of their grain. This was especially true with Lots VIII. and IX. where wheat was a part of the ration. The ration was reduced to one and one-quarter pounds daily per lamb on May 16th, and all the lambs again began to make gains. Corresponding losses, but not in quite such a marked degree, seemed to have occurred during the third and sixth weeks after the lambs were put on feed. The largest total gain

was made by Lot VI. which received the spelt ration and the smallest gain was made by Lot IX. which was fed wheat and spelt.

FOOD EATEN AND GAINS MADE.

Table XIII. gives the total amount of each kind of food eaten, the initial average weight of the lambs in each lot, and the total gain. The weights and gains in Lot IX. are computed from the averages of the four lambs which made normal gains during the feeding period.

TABLE XIII.

FOOD EATEN AND GAINS, IN POUNDS.

	No. of Lambs.	No. Days Fed..	Food Eaten.					Average Weight		Total gain flesh	Fleece.......
			Alfalfa.	Corn...	Wheat.	Barley.	Spelt..	At Beginning	At End		
Lot V....................	5	90	803	402	......	......	......	53.8	78.4	113.	17
Lot VI	5	90	889	......	......	......	430	53.8	78.2	127.0	15
Lot VII.................	5	90	888	......	......	402	......	57.4	76.8	97.0	20
Lot VIII................	5	95	852	....	221	221	... ..	47.2	70.6	117.0	14
Lot IX	5	95	833	......	218	......	218	*57.5	*75.0	**87.5	14

*Average of four lambs.
**Estimated gain of five lambs from averages of four.

TABLE XIV.

FOOD EATEN FOR ONE POUND GAIN.

	Food for One Pound Gain.					Cost 1 lb. Gain	Percent Dressed Weight
	Alfalfa	Corn	Wheat	Barley	Spelt		
Lot V	lbs. 6.17	lbs. 3.09	lbs.	lbs.	lbs.	cts. 5.25	52.1
Lot VI	6.26	....	....	....	3.03	4.28	49.2
Lot VII	7.59	....	....	3.43	....	4.95	48.8
Lot VIII.................	6.50	....	1.69	1.69	....	4.68	49.6
Lot IX	8.20	....	2.14	....	2.14	5.93	59.0

Table XIV. gives the amount of each kind of food eaten for each pound of gain produced and the per cent of dressed weight, with the cost of each pound of gain. There is a marked variation in the per cent of dressed weight. Lot IX. dressed 59 per cent and Lot VII. 48.8 per cent, a difference of over 10 per cent. This condition would have much to do with their value on the market and those with the low per cent of dressed weight would give less profit.

The best general result was obtained with the spelt and alfalfa ration fed to Lot VI. These lambs consumed 6.26 pounds of alfalfa and 3.30 pounds of spelt at a cost of 4.28 cents for each pound of gain. This is very close to the amount of hay and corn for each pound of gain, but because of the high price of corn, which cost us $1.30 per hundred pounds, the cost of each pound of gain was nearly one cent higher than in the spelt ration. If corn was obtained for $1.00, which was the price allowed for the spelt, the cost of each pound of gain would be 4.32 cents, or within .04 cents of the cost of each pound of gain with the spelt ration. This difference is very small and the corn ration lambs dressed almost three percent better than the spelt ration lambs.

The next best result was obtained with Lot VIII. fed wheat, barley and alfalfa. These lambs ate 6.5 pounds of alfalfa and 3.38 pounds of grain composed of equal parts of wheat and barley, for each pound of gain, making the gain cost 4.68 cents per pound. At the same price the corn ration would have produced a little cheaper gain than this, but the farmer could not afford to sell his wheat and barley

TABLE XV.

COST AND PROFIT.

	Feed.	Cost of Feed.	Cost 1 lb. Gain.	Value Gain @ 6 cts.	Value Wool @ 10 cts.	Total Value of Gain.	Profit.
Lot V......	Corn, Alfalfa,	$ 6.83	cts. 5.25	$ 6.78	$ 1.70	$ 8.48	$ 1.65
Lot VI.....	Spelt, Alfalfa,	6.08	4.28	7.62	1.50	9.12	3.04
Lot VII....	Barley, Alfalfa,	5.80	4.95	5.82	2.00	7.82	2.02
Lot VIII...	Wheat, Barley, Alfalfa,	6.12	4.68	7.02	1.40	8.42	2.30
Lot IX.....	Wheat, Spelt, Alfalfa	6.13	5.93	5.25	1.40	6.65	.52

or spelt at one cent a pound and pay the prices which prevailed for corn the past year.

COST AND PROFIT.

Table XV. presents the results of the experiment in the dollars and cents form.

Here is given the cost of food consumed by each lot of five lambs, the value of gain made at six cents per pound, and the total profit on the gains. As before stated, this profit would be increased by the amount of the increased price of the fat lambs over the original cost of the feeders, and the cost would be increased by adding the cost of labor, interest on the investment, etc. Here again the best results were obtained from spelt and alfalfa, the total profit being $3.04. The next best results were obtained with Lot VIII., fed wheat and barley, which produced a profit of $2.30. Lot VII., fed on barley and alfalfa, gave a profit of $2.02, and the profit with the corn and alfalfa fed lot was $1.65. Lot IX., fed wheat and spelt, produced a profit of only 52 cents, probably because this ration was not well balanced.

Had the corn been obtained at the same price as other grains, $1.00 per hundred, the total profit from Lot V. would have been $2.86. This is still not so good a profit as was produced by the spelt ration, but was better than the other grains or combinations of them used in this series of experiments.

It would appear from comparisons of Lots V. and VIII. that when wheat and barley are worth $1.00 per cwt., corn would be worth approximately $1.11 per hundred pounds. This experiment indicates that spelt has a high feeding value, but it would hardly be safe to recommend it without reservation from a single experiment. Further trial will be made with it in the near future. Computing the value of spelt from this experiment, compared with wheat and barley at $1.00 per hundred pounds, it would appear to have a value of $1.13 per hundred, or two cents per hundred more than corn.

Crediting all the profit to the alfalfa as we did in Experiment I., we have a return for the alfalfa fed to Lot V. of $6.42 per ton. The profit on Lot VI. would give the alfalfa a value of $9.48 per ton, Lot VII. $6.77 per ton, Lot VIII. $8.00 per ton, Lot IX. $4.19 per ton.

Comparing profits in Experiment I. and Experiment II., which cover the nine lots of lambs, we have the largest profit from Lot I., fed pulp and alfalfa, and the second best

profit from Lot VI., fed spelt and alfalfa. The third best combination of foods seems to be that given to Lot III., which was fed beets and alfalfa and a small ration of grain during the last thirty days. The wheat and barley gave us slightly better profit than the lot fed pulp, grain and alfalfa. The corn ration gave a lower profit than either of the lots fed pulp or beets with or without grain.

LAMB FEEDING EXPERIMENT NO. 3,

COMPARISON OF HOME GROWN GRAINS WITH CORN, WARM AND COLD WATER. SHROPSHIRE GRADES AND NATIVE LAMBS.

OBJECT AND PLAN OF EXPERIMENT.

During the winter of 1900-01 an experiment was planned to test the value of a mixture of home grown grains compared with corn for fattening lambs, and to determine whether or not there would be any advantage in giving lambs warm water to drink instead of cold water. For this purpose twenty western lambs, half of them Shropshire crosses raised on the College farm, were divided into four lots of five each and given the following rations:

Lot I. was given an equal mixture of oats, wheat and barley with alfalfa and cold water.

Lot II. was fed the same as Lot I., excepting warm water (80-100 F.) was given twice daily instead of cold water.

Lot III. was fed corn, alfalfa and warm water.

Lot IV. was fed the same as Lot III., except cold water was given in place of warm water.

Each lamb was marked with an ear tag and weighed separately once a week. Each lot of lambs was given an equal amount of shed room and the same sized yard to run in, and were treated alike in every respect. Grain, hay and water were supplied twice daily and the orts were weighed back daily. Previous to the time the experiment was begun the lambs had been fed alfalfa and a very small amount of grain, and were in a good thrifty growing condition. One half pound of grain per head was fed daily the first week and this amount was increased to three-quarters of a pound the second week. The grain was gradually increased until March 16, when they were receiving one and three-fourths pounds per head per day.

The prices of food used in this experiment were as follows:

Alfalfa hay on the farm, $4.00 per ton.

Corn, local market, $0.80 per hundred pounds.

Wheat, oats and barley, $1.00 per hundred pounds.

Table XVI. gives for periods of one week, the amounts of the different rations fed and the orts weighed back.

TABLE XVI.

FOOD EATEN, IN POUNDS.

	Lot I.					Lot II.					Lot III.					Lot IV.				
	Oats, Wheat, Barley	Alfalfa	Alfalfa Orts	Water	Water Orts	Oats, Wheat, Barley	Alfalfa	Alfalfa Orts	Warm Water	Warm Water Orts	Corn	Alfalfa	Alfalfa Orts	Warm Water	Warm Water Orts	Corn	Alfalfa	Alfalfa Orts	Water	Water Orts
Jan 23-30.	17	96	27	233	60	17	95	21	233	33	17	96	19	233	50	17	96	24	233	50
Jan. 30-Feb. 7	26	90	13	185	41	26	90	17	185	18	26	90	17	185	21	26	90	17	185	28
Feb. 7-13	35	105	28	210	29	35	105	25	210	27	35	105	24	210	26	35	105	26	210	37
Feb. 13-20	44	103	27	210	43	44	103	30	210	29	44	103	28	210	20	44	103	30	210	30
Feb. 20-27	52	91	24	210	22	52	91	28	210	35	52	91	24	210	21	52	91	24	210	31
Feb. 27-Mar. 7	61	104	38	240	36	61	104	30	240	77	61	104	28	240	23	61	104	29	240	60
Mar. 7-14	56	91	30	225	29	56	91	24	225	43	56	91	26	225	27	56	91	21	225	47
Mar. 14-21	60	91	52	245	40	60	91	54	245	53	60	91	45	245	31	60	91	58	245	58
Mar. 21-28	61	91	39	241	37	61	91	42	241	34	61	91	35	241	26	61	91	52	241	38
Mar. 28-Apr. 4	61	89	37	245	72	61	91	38	245	48	61	91	31	245	36	24	81	33	245	99
Apr 4-11	49	70	32	245	84	59	84	36	245	48	54	91	15	245	33	41	70	23	245	98
Apr. 11-18	49	70	28	245	81	49	70	42	245	99	52	91	40	245	64	45	70	27	245	107
Apr. 18-25	49	70	21	245	73	49	70	34	245	82	31	70	26	245	66	45	70	23	245	72
Apr. 25-May 2	10	40	26	137	26	13	45	43	139	50	22	45	32	145	47	22	45	33	137	46
Totals	630	1201	422	3116	673	643	1221	484	3118	676	632	1250	390	3124	491	589	1198	420	3116	802
Totals for 4 sheep Jan. 23-May 2	536	1091	355	2672	593	538	1014	403	2620	589	518	1123	326	2597	414	509	1026	363	2717	727

FOOD AND WATER CONSUMED.

One ewe was thrown out of each lot on account of dropping a lamb; from Lot I. on April 4, Lot II. on April 11,

Lot III. on April 17, and Lot IV. on March 27. The "totals for four sheep" at the bottom of the table are corrected totals, and the ones from which the results are computed. Since one lamb was thrown out of each lot the results are all computed by using averages of the remaining four lambs.

The lambs in Lots I. and II. ate more of the mixed grains than the lambs in Lots III. and IV. ate of corn. The corn fed lots in turn consumed more alfalfa than the grain fed lots. The water drank by the two grain lots and that drank by the two corn lots is practically equal. The two lots which were given warm water drank 145 pounds in excess of that drank by the two lots which received cold water. This would be and average of one-fifth of a pint per head daily.

Table XVII. gives the average amounts of food and water actually consumed by each lamb daily.

Lots I. and II. ate more of the mixed grain daily than Lots III. and IV. ate of corn, but the grain fed lots ate a little less hay per day than the corn fed lots.

TABLE XVII.

AVERAGE FOOD EATEN DAILY, IN POUNDS.

	Water.	Alfalfa.	Corn.	Mixed Grain.	Total Food
Lot I	5.17	1.85		1.35	3.20
Lot II	5.12	1.54		1.36	2.80
Lot III	5.51	2.01	1.30		3.31
Lot IV	5.02	1.67	1.28		2.95

WEIGHTS AND GAINS.

Table XVIII. gives the individual weights and gains for each week while the lambs were on feed. This table also gives the amount of wool produced by each lamb, and the total gain including the fleece. The Shropshire crosses are indicated in the table and enable comparison to be made between them and the western lambs.

It will be noticed that the Shropshire crosses made much better individual gains than did the other lambs. The two Shropshire crosses in Lot I. made an average total gain of 35.5 pounds, which was the same as the gains made by the other two lambs. In Lot II. the two Shropshire crosses made an average total gain of 36.5 pounds, and the other two lambs gained an average of 26.5 pounds.

In Lot III. the three Shropshire crosses made an average total gain of 40.6 (plus) pounds, and the other lamb made a total gain of 36 pounds.

In Lot IV. the two Shropshire crosses made an average total gain of 43 pounds, the other two lambs an average gain of 29 pounds.

TABLE XVIII.

INDIVIDUAL WEIGHTS AND GAINS, IN POUNDS.

	Lot I.					Lot II.					Lot III.					Lot IV.				
	Shrop Cross..				Shrop Cross...		Shrop Cross...	Shrop Cross...			Shrop Cross...			Shrop Cross...	Shrop Cross...		Shrop Cross...			Shrop Cross...
Tag No	594	666	669	674	682	670	673	675	679	683	663	664	681	685	591	593	668	678	684	686
January 23	55	109	81	81	85	74	92	97	78	96	80	91	96	93	66	71	84	90	92	92
January 30	55	110	83	82	89	75	90	99	79	97	81	92	98	94	68	71	85	92	94	94
February 7	57	114	83	86	90	79	93	101	80	103	84	94	102	98	68	76	92	98	95	96
February 13	62	118	86	90	94	80	95	102	80	107	87	99	104	101	70	77	94	99	101	97
February 20	64	121	91	93	95	82	95	106	87	110	90	103	111	107	74	81	97	104	105	100
February 27	67	126	90	97	97	84	99	110	87	115	9	106	111	110	81	84	101	109	110	104
March 7	72	131	94	97	103	88	104	116	89	118	97	112	114	113	85	86	105	112	113	108
March 14	74	136	94	103	106	90	108	119	92	124	98	117	120	115	90	88	109	116	117	112
March 21	77	138	105	106	110	91	110	124	91	126	102	122	124	120	94	90	112	118	121	115
March 28	81	147	104	111	112	93	115	128	96	135	105	129	128	122	102	94	119	120	128	118
April 4	85	150	102	114	115	95	116	133	98	126	106	133	129	120	101	93	114	117	*	116
April 11	88	*	109	119	114	102	122	139	103	*	110	138	133	127	108	98	124	125	*	124
April 18	90	*	114	122	122	103	123	136	104	*	112	*	137	129	109	100	125	126	*	126
April 25	86	*	105	111	115	93	115	131	95	*	103	*	125	122	102	93	119	115	*	119
May 2	89	*	104	113	110	96	121	125	90	*	109	*	121	119	110	91	122	112	*	122
Fleece	4		7	9	8	10	7	9	9		8		11	9	6	5	9	11		9
Total Gain	38		39	41	33	32	36	37	21		37		36	35	50	25	17	32		39

*Thrown out.

The nine Shropshire crosses in the experiment averaged 39.1 pounds gain. The seven native lambs averaged 31 pounds gain, or 21.8 percent less than the Shropshire crosses. This shows the advantage of good blood, and of a mutton cross on the native sheep to produce profitable feeders. The Shropshire grades averaged 7.7 pounds of fleece, and the native lambs averaged nine pounds of fleece.

The table indicates that the lambs made remarkably even gains.

Table XIX. gives the pounds gain per week by each lot. There are some variations week by week, but the weeks which record losses are few. Except in the final week of the experiment, when the weights were taken after 24 hours shrinkage with the lambs off feed, there are but two instances of recorded loss of weight, both of them in the corn fed lots. The gains for May 2d were from the final live weight of the lambs after they had been off feed and water for twenty-four hours.

TABLE XIX.

POUNDS GAIN PER WEEK.

	Lot I.	Lot II.	Lot III.	Lot IV.
January 30	7	2	6	5
February 7	7	10	11	20
February 13	16	4	10	5
February 20	11	10	20	15
February 27	8	13	12	16
March 7	15	17	15	13
March 14	11	12	14	14
March 21	21	7	17	10
March 28	10	16	17	16
April 4	8	10	1	–11
April 11	14	24	22	31
April 18	18	0	9	6
April 25	–3	3	–1	3
May 2	–1	–2	7	1
Total Gain Flesh	114	91	124	110
Fleece	28	35	32	34
Total Gain with Fleece	142	126	156	144

Lot III. fed corn, alfalfa and given warm water to drink made the largest total gain. Lot IV., fed the same ration as Lot III., except that they were given cold water to drink, made the second largest gain. Then followed Lot I. and II. in order. The average total gain of Lots I. and II., the mixed grain lots, is 134 pounds; the average total gain of Lots III. and IV., the corn fed lots, is 151 pounds, or an average of 17 pounds more of the four lambs in the corn fed lots than in the two mixed grain lots. As shown in Table XX., Lot I. given cold water, gained 16

pounds in excess of Lot II., given the same ration, but having warm water instead of cold water. Lot III., given the same ration as Lot IV., except they were given warm water to drink, gained 14 pounds more. Warm water appeared to have the advantage in the latter lots, but in the former the greater gain was made when cold water was given.

If then warm water had any effect either way, there are other conditions which obscured the results.

AMOUNT AND COST OF FOOD COMPARED WITH GAINS.

Table XX. gives the total amount of food eaten and water drank and the total gain made by each lot during the experiment. By the use of this table the feeder can compute for himself the cost of food and value of gains under his own conditions.

TABLE XX.

FOOD, WATER AND GAIN IN POUNDS.

	No. of Lambs.	No. Days Fed.	Food Eaten and Water Drank. Alfalfa	Mixed Grains	Corn.	Water Drank	Average Weight. At Begin'ing	At End	Total gain flesh	Fleece.......
Lot I......................	4	99	736	536		2079	75.50	104.0	114	28
Lot II......................	4	99	611	538		2031	85.25	108.0	91	35
Lot III......................	4	99	797		518	2183	83.75	114.75	124	32
Lot IV......................	4	99	663		509	1990	84.25	111.75	110	34

The corn fed lots show a total average gain of 151 pounds, which is to be compared with a total average gain of 134 pounds in the small grain lots. For this gain it took an average of 513.5 pounds of corn in Lots III. and IV., and 537 pounds of oats, wheat and barley in Lots I. and II.

In Table XXI. will be found the amount of food eaten to produce each pound of gain, the cost of each pound of gain and the average percent of dressed weight in each of the trials. As no effect can be traced to the warmth of the water supplied we may average the results from Lots I. and II. fed the grain mixture, and those of Lots III. and IV. fed corn. Then with the corn ration it took 4.89 pounds of alfalfa and 3.37 pounds of corn to produce each pound of gain at an average cost of 3.67 cents. With the home grown grain mixture it took 5.01 pounds of alfalfa and 4.02 pounds

of grain to produce each pound of gain at a cost of 5.02 cents. The corn fed lots made an average dressed weight one and one-half percent higher than the small grain fed lots. Then the alfalfa eaten is so nearly equal in each lot, we may say that 100 pounds of corn was equal in fattening value to 119 pounds of wheat, oats and barley.

TABLE XXI.

FOOD EATEN FOR ONE POUND GAIN.

	Food and Water for One Pound Gain.				Cost 1 lb. Gain.	Percent Dressed Weight.
	Alfalfa.	Mixed Grains.	Corn.	Water.		
	lbs.	lbs.	lbs.	lbs.	cts.	
Lot I.	5.18	3.77		14.64	4.81	63.4
Lot II.	4.84	4.27		16.12	5.24	61.2
Lot III.	5.17		3.21	14.17	3.60	63.2
Lot IV.	4.60		3.53	13.82	3.74	64.7

COST AND PROFIT.

The comparative cost and profit of the different lots is obtained by figuring the gain made at six cents per pound and the wool produced at 10 cents per pound. This gives the total value of the gain from which is subtracted the cost of the food consumed. There is a marked difference in the cost of the food for the different lots even when fed on the same ration. Referring to Table XXII. it will be noted that Lot I. ate 23 cents worth more of food per lamb than Lot II., although both were fed the same ration of grain,

TABLE XXII.

COST AND PROFIT.

	Feed.	Cost of Feed.	Cost 1 lb. Gain.	Value Gain @ 6 cts.	Value Wool @ 10 cts.	Total Value of Gain.	Profit.
		$	cts.	$	$	$	$
Lot I.	Cold Water, Alfalfa, Mixed Grain	6.83	4.81	6.84	2.80	9.64	2.81
Lot II.	Warm Water, Alfalfa, Mixed Grain	6.60	5.24	5.46	3.50	8.96	2.30
Lot III.	Warm Water, Alfalfa and Corn.	5.73	3.60	7.44	3.20	10.64	4.91
Lot IV.	Cold Water, Alfalfa and Corn.	5.40	3.74	6.60	3.40	10.00	4.60

and Lot III. ate 33 cents worth more of food per lamb than Lot IV., both being fed corn.

The cost of the food eaten by Lots I. and II. is higher than that eaten by Lots III. and IV., principally because the small grains were more valuable than corn at the time the experiment was carried on. The small grains fed Lots I. and II. were worth $1.00 per hundred pounds, which at that time was 20 cents more than the selling price of corn. The total profit from the eight lambs which were fed wheat, oats and barley was $5.11, while the total profit from the eight lambs fed corn was $9.51.

Attributing all the profit to the alfalfa eaten we find that the average of the small grain fed lot gives a return of $7.58 per ton for the alfalfa consumed, and the corn fed lots gave an average return of $13.03 per ton for the alfalfa consumed. Taking into account the oats in this ration, which are of doubtful value for sheep feeding, and the fact that the lambs were larger than those reported in Experiments I. and II. and were in much better condition at the beginning of the feeding period, the comparative values of the small grains and corn for lamb feeding correspond very closely in all of the experiments reported in this bulletin.

GENERAL SUMMARY.

Beet pulp is a valuable roughage to feed with alfalfa, and we believe would be especially valuable to use during the first part of a feeding period. Pulp fed mutton had good flavor, but was not very fat.

Pulp and alfalfa fed lambs made gains at the least cost per pound, and gave us the largest profit last winter. The second best profit was from lambs which were fed spelt and alfalfa. The third best combination of foods used from the profit standpoint was beets and alfalfa with a ration of grain the last thirty days, decreasing the amount of beets fed at the end of the feeding period. Wheat, barley and alfalfa gave a little better profit than alfalfa, beet pulp and grain. The corn ration gave the least profit when compared with any of the lambs which were fed beets or pulp.

Beet pulp, which does not cost the feeder more than $1.50 per ton at his yards, will give a return sufficiently large to pay for using it in a ration, but we would not recommend letting lambs eat so much of it during the finishing period that they will not consume good rations of hay and grain.

Sugar beets did not prove to have a high feeding value for lambs. It is doubtful if farmers can afford to feed beets to lambs if they can sell them to a factory at $4.50 per ton, and the conditions must be favorable to make beets give a return sufficiently large to pay for raising them. Two pounds of sugar beets were equal to about one pound of pulp.

Sugar beets and poor kinds of roughage cannot be made to take the place of alfalfa hay.

These trials showed that at the same price corn had a feeding value greater than a mixture of wheat, barley and oats, or wheat and barley, or barley alone.

Our single trial with Russian spelt showed it to have a feeding value at least equal to corn, and greater than wheat and barley.

Shropshire grade lambs made much better gains than common western lambs when fed the same ration. Nine Shropshire grades made average gains of 43.6 pounds, and seven native western lambs made an average of 31 pounds.

Our trials with warm and cold water given to fattening lambs did not show any advantage of one over the other.

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Feeding Beet Pulp to Lambs.

—BY—

H. H. GRIFFIN.

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Feeding Beet Pulp to Lambs.

By H. H. Griffin.

The establishment of beet sugar factories in Colorado placed the pulp at the command of the farmer for use as stock food after the extraction of sugar. The writer realized that there would be much demand on the part of feeders for reliable information in regard to the value of this product for sheep feeding, as the feeding was done principally for this purpose and probably would be for years to come. The writer further realized that this demand would be emphasized in times of short corn crops in the east and consequent high-priced corn in the Arkansas valley.

It was the wish of the writer to do some experimental feeding with this product in the way of comparing it with corn for fattening sheep. By the kindness of Mr. F. M. Harsin, of Rockyford, 250 head of lambs were placed at our disposal to make a test.

The experiment was planned as follows: One car load of lambs was to be divided into two lots. Each lot was to receive the same amount of alfalfa hay daily. One lot was to be fed corn as it is customary to feed corn in this country. The other lot was to receive pulp in lieu of corn in such amount as would be deemed best for the purpose of making the comparison.

Further, it was intended to incidentally note the effect of the pulp upon the health of the sheep, on the amount of water drank, upon the quality of the meat, and to note how pulp-fed lambs would ship to market as compared to corn-fed lambs. The writer realized that in the latter proposition was, to a great extent, the crucial test of its value.

These lambs were a grade lot from the San Luis valley. Mr. Harsin had put them on hay and corn the first week in November. At the time the Station received them, in December, they were getting 7 oz. of corn per head per day. They were weighed into the Station's pens on the 24th day of December, 1900, 125 in each pen. The weight of pen I was 7,632 pounds or an average of 61 pounds per head; of pen II, 7,772 pounds or an average of 62 pounds per head. Each lot was given the same amount of hay daily. But few of the lambs took to pulp readily. It was ten days before all the lambs in pen II were eating pulp. Pen I was continued on 7 oz. of corn per head daily.

February 21st a stampede of the sheep occurred by which a

few of the corn-fed lambs became mixed with those fed on pulp. They had not been marked, but as those not used to pulp refused to eat it, the separation was easily made.

Both lots were weighed January 3d, and thereafter as often as fortnightly. Pen I weighed 7,710 pounds and pen II 7,744 pounds, so that by the time pen II was eating pulp both lots weighed practically the same.

Pen I was now increased to 9 oz. of corn per head per day. Pen II was consuming 500 pounds of pulp daily, four pounds per head daily, equivalent to 6.4 oz. of dry matter. They were wasting some of this amount of pulp. Both lots were taking practically the same amount of hay, two pounds per head daily. Pen II was held to about 500 pounds of pulp daily until February 2d. At this time the pulp was increased to 750 pounds daily for three days, after which it was increased to 1,000 pounds daily.

It was found that the lambs would not consume this amount of pulp, and that there was also a diminution in the amount of hay eaten. Consequently, in three days the pulp was reduced to about 800 pounds daily, an average of about 6½ pounds per head. The amount fluctuated some because of the waste which occurred. Lot II was continued on this amount of pulp until March 4th.

The corn-fed sheep—pen I—were fed in the same way, gradually increasing the corn, as is the general practice in this section. January 14th they were increased to 11 oz., on February 2d to 13 oz., on March 5th to 16 oz. per head per day. One pound daily per head was the greatest amount because it was difficult to secure corn, and further because the dry matter being fed the pulp lot did not equal in amount that fed the corn lot.

It was apparent that the supply of pulp would be exhausted before the lambs would be in proper condition for market. For this reason it was planned to add corn to the pulp ration and as soon as possible get the corn up to such an amount as the dry matter in the pulp and corn would equal that in the corn lot. Accordingly, on March 5th, the pulp was reduced to 400 pounds daily and 6 oz. of corn added per head daily. The corn lot—pen I—was getting one pound of corn per head daily.

March 27th the corn in the pulp lot—pen II—was increased to 10 oz. of corn daily; the pulp and corn were estimated to contain the same amount of dry matter as the one pound of corn pen I was receiving. Both lots were continued on this ration until the lambs were shipped, on April 16th.

Both lots were weighed at the Station on April 13th. Pen I, which was now reduced to 122 sheep, weighed 10,532 pounds, an average of 86.3 pounds. Pen II (123 sheep) weighed 10,340 pounds, an average of 84 pounds per head.

April 16th the lambs were put on the cars for shipment to

Kansas City. Pen I (121 sheep) then weighed 10,490 pounds, an average of 86.7 pounds per head. Pen II (122 sheep) weighed 10,-373 pounds, an average of 85 pounds per head. One sheep from pen II, while being driven to the cars, broke its leg and was not shipped. Four sheep were killed in pen I, two of which were butchered. Pen I thus gained 1.7 pounds per head more than pen II, comparing the weights from January 3d to the close of the feeding.

The weather of December 30th to January 1st was severe, averaging -6° on the 31st, but the gain made by the lambs was fairly good.

TABLE I.

PERIOD.	No. Days.	Hay. Lbs.	Refuse. Lbs.	Corn. Lbs.	Water. Lbs.	Gain. Lbs.
December 24-30	7	1,494	52	351	1,783	
December 31—January 4	5	1,134	86	291	1,575	78
January 5-14	10	2,504	355	708	4,050	279
January 15-24	10	2,250	350	860	4,040	513
January 25—February 2	9	2,125	516	781	3,175	74
February 3-13	11	2,250	325	1,000	3,625	316
February 14-23	10	2,500	270	1,100	4,605	
February 24—March 5	10	2,500	621	1,012⅝	5,360	818
Total	72	16,757	2,575	6,103⅝	29,213	2,078
March 6-27	22	5,588	730	2,750	11,900	652
March 28—April 13	17	4,178	533	2,090	7,200	128
April 14-16	3	680	200	302		44 +
Total	114	27,203	4,038	11,245½	48,313	2,902+

TABLE II.

PERIOD.	No. Days.	Hay.	Refuse	Pulp.	Refuse	Corn.	Water.	Gain.
December 24-30	7	1,527	44	1,780	195		1,275	
December 31—January 4	5	1,134	66	2,325	41		575	-28
January 5-14	10	2,504	379	5,038	92		1,300	216
January 15-24	10	2,250	270	5,020	79		1,675	257
January 25—February 2	9	2,125	268	4,732	22		1,050	131
February 3-12	10	2,250	386	8,671	369		300	276
February 13-23	11	2,500	338	8,969	98		365	
February 24—March 5	10	2,500	661	7,757	102		665	858
Total	72	16,790	2,412	44,292	998		7,205	1,710
March 6-27	22	5,588	870	9,371	46	988	5,075	
March 28-April 16	20	5,607	1,073	6,825		1,607½	3,425	498
Totals	114	27,985	4,355	60,488	1,044	2,595½	15,705	2,678

TABLE III.

DATE.	PEN I.				PEN II.			
	No. Sheep.	Gross Wt. Lbs	Gain. Lbs.	Wt. Per Head.	No. Sheep.	Gross Wt. Lbs.	Gain. Lbs.	Wt Per Head.
December 24	125	7,632		61.0	125	7,772		62.1
January 3	125	7,710	78	61.6	125	7,744	-28	61.9
January 14	125	7,989	279	63 9	125	7,960	216	63.7
January 24	125	8,502	513	68 0	125	8,217	257	65.7
February 2	125	8,576	74	68.6	125	8,348	131	66 7
February 12	125	8,892	316	71.0	125	8,624	276	69.0
March 5	125	9,710	818	77 6	125	9,482	858	75.8
March 27	124	10,362	652	83 5	124	9,952	470	80.2
April 13	122	10,532	170	86.5	123	10,340	388	84.0
April 16	121	10,490	-42	86.6	123-122	10,450-10,373	90	85.0
April 18 (K. C.)	120	9,280	-1,210	77 3	117	8,880	-493	75.9

TABLE IV.

Date.	Weather.	Water Drank Pen II—Lbs.	Water Consumed as Pulp, Pen II. lbs	Total Water Consumed, Pen II, lbs	Water Drank Pen I—Lbs.
January 1...	Cold	100	390	490	300
January 15..	Mild	115	441	556	315
February 1..	Cold	100	461	561	300
February 8..	Cool	0	900	900	300
March 1.....	Very Warm	100	750	850	575
March 15....	" "	325	375	700	675
April 1......	Stormy	50	360	410	200
Total......		790	3,677	4,467	2,665

Feeding experiments nearly always show a lack of uniformity in gains, though the weather and kind and amount of food may be constant.

Comparing the gain with the amount of food eaten, the pulp lot compares quite favorably with the corn-fed lot. Were the test to stop here, favorable claims could be made for the pulp. The crucial test came in the shipping. The lambs were forty hours on the way from Rockyford to Kansas City without feed. The shipping showed that the pulp lot were weak-boned and had but little stamina; that the flesh was soft and shrank immensely, giving a much worse appearance than the corn-fed ones.

On the cars four sheep died and one was crippled in the pulp-fed lot; one was crippled in the corn-fed lot. The lambs sold for \$4.80 per cwt., the market being from \$4.60 to \$5.00 that day. The pulp lot in Kansas City had an average weight of 75.8 pounds. The corn lot had an average weight in Kansas City of 77.3 pounds. In shipment the corn lot lost 9.4 pounds per head, and the pulp lot 9.2 pounds. The amount each lot shrank is practically the same. The four dead sheep were, of course, a total loss, which with three crippled (one corn–fed) ones indicates the lack of strength as compared with the other sheep. The attendant stated that the pulp lot sold higher than they would have had not they been on the market in small numbers with corn-fed lambs. Thus while the average weights are about the same, the deaths in pen II and the general appearance of the lot plainly evidenced that they did not ship nearly so well as the corn-fed lot.

The financial account based on the Kansas City returns stands as follows:

117 lambs (fed on pulp), 8,880 lbs., at \$4.80..............\$426.24. Per head, \$3.64
120 lambs (fed on corn), 9,280 lbs., at 4.80.............. 445.44. Per head, 3.71
Balance in favor of the corn.......................... 19.20. Per head, .07

If the lambs had been fed pulp exclusively until the time of shipment, I have every reason to believe that the per cent. of loss would have been much greater. Salt was given both lots twice per week, the pulp lot getting one-third more than the others. Evidently lambs fed on pulp should be given plenty of salt because of the absence of bone-forming material in the food.

March 20th one lamb from each lot was sold to local butchers

to test the quality and appearance of the meat. March 28th two more lambs, one from each pen, were sold for the same purpose. Both lots dressed well and the proportion of dressed meat was about the same. The corn-fed flesh was considered some best in color and the carcass showed a good proportion of fat on the outside. The carcass of the pulp-fed lamb showed the most fat on the inside.

The meat from each lot was of good quality and but little, if any, difference could be noted. At the time of loading on the cars one of the pulp lot broke a leg. The lamb was killed and dressed, but it dressed out very poorly. There was but little fat and the meat was of poor quality. This was a typical Navajo sheep, which may account for the failure to put on fat.

As pen II did not become accustomed to pulp until January 3d, the only safe comparison of gains that can be made is for a feeding period of 60 days between January 3d and March 5th.

Referring to table I, we find that for this period pen I ate 5,590 pounds of corn and gained 2,000 pounds. Pen II ate 41,117 pounds of pulp and gained 1,728 pounds. Both lots had eaten practically the same amount of hay. It required 2.79 pounds of corn, in addition to the hay, to make one pound of gain. It required 23.78 pounds of pulp, in addition to the hay, to make one pound of gain. These figures, reduced to their equivalents in dry matter, make 2.37 pounds and 2.34 pounds, respectively. The amount of gain corresponds very closely to the amount of dry matter in the food. Were the pulp so condensed that the same amount of food material could be consumed as of corn, it can fairly be said the results would be equal. These results are based upon the weights at the shipping yards and not at the point to which the lambs were shipped.

Pulp is not a condensed food and the capacity of the animal to take it is limited. The results from the pulp may be partially due to the cooling and regulating effect it may have upon the system. The office of the pulp would seem to be as follows:

On account of its cooling and regulating effect on the system, and bulky, succulent nature, it would be a good thing to feed for some time after taking lambs from the range and putting them on dry hay. For the first two months of feeding the feeder does not care so much for the fat put on the animal as he does for the growth and for the enlargement of the animal's digestive capacity. The alfalfa produces the growth and enough pulp can be consumed to fatten as fast as is desired in the early stages of the feeding.

After the first two months of feeding I believe the lambs should be gradually accustomed to corn, and for the last six weeks of the feeding the pulp should be kept from them entirely.

What, then, is the value of a ton of pulp for feeding to lambs as compared with corn, based upon the results obtained in this feeding trial? The computations so far in this bulletin have been made

upon the supposition that pulp contains 90 per cent. water, which is about right for the pulp we fed. One ton of pulp, therefore, contains 200 pounds of feeding material. For comparison we will consider corn worth, at the cars, 75 cents per cwt. A ton of pulp may be said to be worth $1.50, could it be fed without any outlay for transportation.

The great consideration in estimating the value of the pulp is the matter of transportation. For convenience we will estimate the feeder is such a distance from a factory that it costs him $1.00 per ton to deliver corn to his yards. The corn at above rates costs him, then, 80 cents gross per cwt. It will take practically the same time to deliver a ton of pulp as it does a ton of corn. It has cost, then, to get the pulp $1.00 per ton. This would leave 50 cents for the value of a ton at the factory. If the pulp is shipped then the freight charges must also be deducted to obtain the price which the feeder so situated may afford to pay for the pulp at the factory.

Let us inquire for a moment as to the amount of labor required to transport the same amount of feeding material in pulp as there is contained in ten tons of corn. We will suppose that the feeder is such a distance from the station that he can haul the above amount of corn in 15 hours, or at the rate of one ton in one and one-half hours. The trip can be made with pulp in about the same time, but two and one-half tons of pulp can be hauled at each load because it is of the same bulk as two tons of corn. To haul a ton, which contains 200 pounds of feeding material, the cost then is $1.50. To get a ton of feeding material in the pulp it will take 12 hours; to get the ten tons of feeding matter it will require 120 hours. The cost at 30 cents per hour for man and team will be $4.50 for the delivery of the corn, and $36.00 for the delivery of the pulp.

It may be said that the farmer has the pulp as a by-product of the beet business, and that it will be a waste unless he utilizes it for feed.

Under similar conditions for which the above estimate is made, let us see what it may be considered worth to such a farmer for lamb feeding. The corn will cost him 77 cents per hundred weight (approximately) at the feeding yards. The pulp has cost him only the delivery, or $36.00, which equals 36 cents per ton, or 18 cents per hundred weight dry matter; 77 cents minus 18 cents equals 59 cents, the value per hundred weight of the dry pulp. As there are 200 pounds in each ton, then 59 cents × 2 cents, or $1.18. From this must be deducted the expense of delivering the pulp (labor of handling), together with the labor necessary to get the pulp from the silo to the sheep – a total of not less than 20 cents per ton. Deduct this from the $1.18 will leave 98 cents per ton as the value that may be attached to it by a farmer so situated.

Mr. Rhodes, of Las Animas, has feeding yards about one mile from the depot. He delivered a considerable amount of pulp to his yards in the fall of 1901. The pulp cost him at the factory 25 cents per ton and the freight was 30 cents per ton, making it cost 55 cents at the railway station. He used a four-horse team and one man to deliver the pulp. He estimates that the total cost delivered at the pen was 75 cents per ton, and when fed from the silo the total cost was 85 cents per ton.

The Station received from the factory 86,410 pounds of pulp, of which 59,576 pounds were eaten by the lambs, leaving 26,834 pounds, or 32 per cent., as the amount of waste or loss. This may be considered as a maximum waste, as we had no silo in which to store the pulp.

Some trouble was experienced in feeding the pulp in very cold weather on account of freezing. At such times it was found necessary to wait until about 9 o'clock in the morning before feeding. Again in the afternoon it was necessary to feed at 3 or 4 o'clock so that the pulp could be eaten without freezing. With large lots of sheep this would be a matter of much consideration.

A record was kept of the amount of water drank by each pen, and is given in table II. The result is interesting, as the question is often asked: "How is it that the animals can consume so much watery material in addition to other food?"

The table shows that, including the water in the pulp, the total amount of water consumed by pen II was greater than that received by pen I. The feeding of pulp is simply one way of furnishing the water supply.

The experience in feeding pulp by different people, 1901, shows that where the animals are confined in pens that the yards become extremely wet. Such conditions are not favorable for the growth of the animal and reduce the benefits derived from the food.

SUMMARY.

Sugar beet pulp contains about 90 per cent. of water, hence there is but 200 pounds of feeding material in a ton.

From weighings made on the sub-station farm the results show about equal gains in weight for the dry matter in the corn and in

the pulp when each are combined with alfalfa.

Hence one ton of pulp is equal to 200 pounds of corn.

Owing to the bulky nature of the pulp not enough of it can be consumed by lambs to produce sufficient fat to finish them; hence it should be fed to the greatest extent at the commencement of feeding.

What is fed in the latter part of the feeding period should be used as an appetizer and a regulator of the bowels rather than for the fat it produces.

Pulp fed in large quantities produces a soft flesh.

The matter of transportation is a very essential one for the farmer to consider in the utilization of pulp. For the profitable use the yards must be near the factory or to railway facilities.

When large quantities of pulp are fed to animals confined in small lots the lots become very foul, much to the discomfort of the animals and loss to the feeder.